LAKE AND RIVER ENHANCEMENT
DIAGNOSTIC STUDY
FOR
INDIAN CREEK WATERSHED

Prepared for:

INDIAN CREEK WATERSHED
STEERING COMMITTEE

Prepared by:

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I. INTRODUCTION

The Indian Creek Watershed is approximately 110,000 acres in size and the 43 miles of main channel is a tributary of the East Fork of the White River. According to the Indiana DNR, about a fourth of that is cropland acreage and a fourth of this cropland acreage is eroding above tolerable levels. It is believed that excess sediment and nutrients, coming from the streambanks, may be having a negative impact on downstream mussel populations. Also, the fishery in the lower third of the stream appears to have diminished in recent years.

This is the first of two (Indian Creek and Chain-of-Lakes State Park) watershed diagnostic studies in the State of Indiana, to be funded by the T by 2000 Program that focuses on a stream watershed instead of a lake watershed. We are hopeful and confident that the Soil & Water Conservation Districts (SWCD) of the counties involved will find our report to be a significant milestone on the trail towards dealing with the water quality degradation of Indian Creek.

This project is intended to describe conditions and trends in Indian Creek and its watershed and to identify potential water quality problems in sub-watersheds. This assessment is to provide guidance for future land treatment project selection and to predict the impacts of those projects to Indian Creek. A diagnostic study takes a good look at conditions in the stream and in the watershed to try to understand or diagnose circumstances that, collectively, may be contributing to the water quality degradation suspected of occurring. The purpose of this diagnostic study then is to:

* Describe conditions and trends in Indian Creek and the sub-watersheds,
* Identify potential nonpoint source water quality problems,
* Propose specific direction for future work,
* Predict and assess success factors for future work.

While a diagnostic study is a significant milestone, it can't stop there. The SWCDs will need to commit themselves to going forward with design and implementation of watershed land treatments that may be recommended for the watershed.

II. STREAM & WATERSHED SETTING

1. Location

Indian Creek is a tributary of the East Fork of the White River. The main channel is forty-three miles in length originating in southwestern Monroe County and flowing through Greene and Lawrence Counties until its confluence with the East Fork of the White River in Martin County. The head of the stream is found near Bloomington, Indiana, while the mouth is located near Shoals, Indiana.

2. Morphometry

Indian Creek has a stream length of approximately 43 miles. The straight-line distance between the head of the stream and the confluence with the White River is approximately 28 miles. The elevation at the head of the stream is in the vicinity of 800 Mean Sea Level (MSL) while the mouth of the stream is at approximately 450 MSL. Therefore, the channel slope is calculated to be around 0.15% (8 feet per mile) while the overall valley profile is approximately 0.23% or 12 feet per mile.

3. Watershed Size and Characteristics

The Indian Creek watershed is approximately 171 square miles (110,000 acres) in size. The basin is unusually narrow (west to east) in that it rarely is over eight miles wide while the length (north to south) extends some 28 miles. Upland areas are distinctly dissected with diverse topographic features. Drainage patterns are well defined; however, subwatershed divides are typically flat but narrow while the valley walls are steep. The bottomlands of the large valleys are moderately wide flood plains and are typically the only level soils found in the watershed.

The watershed lies in four counties: Greene, Lawrence, Martin, and Monroe Counties. Table II-1 shows the relative and actual size of each county representation.

Table II-1
Indian Creek Watershed
Relative & Actual Size by County

County	Acreage	Square Miles	% Of Total
Greene	19,900	31.1	18.1
Lawrence	31,400	49.1	28.5
Martin	36,200	56.6	32.9
Monroe	22,500	35.2	20.5
Total	110,000	171	100.0

Significant sub-watersheds include Opossum Creek, Sulphur Creek, Spring Creek, Popcorn Creek, and Little Indian Creek. Table II-2 shows the relative and actual size of these sub-watersheds and the percentage of the entire watershed they represent.

Table II-2
Sub-watersheds of Indian Creek

Watershed	Acreage	Square Miles	% Of Total
Opossum Creek	5,400	8.4	4.9
Sulphur Creek	19,000	29.7	17.4
Spring Creek	7,900	12.3	7.2
Popcorn Creek	9,700	15.2	8.9
Little Indian Creek	6,800	10.6	6.2

The watershed as a whole drains generally to the south.

Opossum Creek receives runoff from the extreme southeast corner of Crane Naval Surface Warfare Center (Crane). All of this watershed area is in Martin County. This area is generally managed forestland. Contributing areas outside Crane include unincorporated towns of Dover Hill and Trinity Springs as well as additional areas of forest, pasture, and cropland. Identified tributaries include Poss Creek with its tributaries of Sum Creek, Dover Run, Hill Branch, and Opossum Run. This subwatershed is found nearest to the confluence of Indian Creek with the East Fork White River and, as such, has characteristically wide flood plains.

Sulphur Creek is the largest subwatershed of Indian Creek watershed as it accounts for 17.4% of the total area. Approximately one-half of that area is managed forestland of the southeast sector of Crane. Areas outside of Crane include the north area of Trinity Springs, Indian Springs, Cale, and the Padanaram commune. Little Sulphur Creek is an identified tributary of Sulphur Creek with a watershed of some 3,900 acres. Little Sulphur Creek receives most of its drainage from managed forest areas of Crane.

Town Branch has a watershed of approximately 3,400 acres, which includes the watershed of Cole Branch. This stream receives runoff from the town of Owensburg, the Tunnel Hill area, and other rural areas of Greene County. A small percentage of the watershed is Crane property located in Martin County.

Spring Creek is situated east of Indian Creek and has approximately 7,900 acres of watershed located entirely in Lawrence County. Towns in this watershed include Springville and the Red Hill area. Tributaries such as Hog Hollow, Linden Hollow, and Speed Hollow feed Spring Creek.

Popcorn Creek is the next identified tributary north of Spring Creek. This stream has a watershed of 9,700 acres. Topographic maps identify the settlement of Popcorn, which apparently was a larger cluster of homes in the past than it is today. The watershed is located in Lawrence and Monroe Counties.

Little Indian Creek has its confluence with Indian Creek in Greene County; however, the vast majority of the stream and its 6,800-acre watershed is in Monroe County. The town of

Kirksville is at the east edge of this watershed. Given the proximity to Bloomington, Indiana, this area has developed substantially as a residential area.

The upper reaches of Indian Creek have watershed areas in Greene and Monroe County including Stanford and Elwren. This area is experiencing on going residential development associated with the City of Bloomington.

There are numerous other named and unnamed tributaries of Indian Creek, which occur along the reach of Indian Creek, which is approximately 43 miles long. Hobbieville is an unincorporated town within a mile of Indian Creek in Greene County. Drainage from this town flows east to Indian Creek and west to Mitchell Branch, a small tributary of Indian Creek.

A second Little Indian Creek is found east of Indian Creek. This stream has a watershed of approximately 3,000 acres, which is located in southeastern Greene County. There are no mapped towns identified in this watershed.

Proceeding downstream there is Boone Hollow, which originates in the managed forestland of Crane in Martin County. East of Indian Creek in that general area is Hert Hollow. Silverville Branch is found further to the south. This stream provides drainage for the town of Silverville, which is along the stream within a mile of Indian Creek.

4. Geology

Southwestern Indiana is underlain by bedrock of the Pennsylvanian age and Mississippian age, both of which dip southwest into the Illinois Basin. At least three glacial advances extended into Indiana during the Pleistocene Epoch and left two sheets of till. The Kansan, Illinoian, and Wisconsin glacial advances extended to areas west and north of the Indian Creek watershed. The Kansan Glacier advance is not easily recognized as it is actually under the more recent advance of the Illinoian Glacier. The watershed is unglaciated and since the glaciers stopped short of the Indian Creek watershed area, the glaciers did not flatten this area and cover it with rich glacial till soil. The landscape was affected however as water from melting glaciers carved out stream beds. After the glaciers retreated, flows of water were reduced drastically and consequently, streams began meandering.

During the Wisconsin Glaciation, which was some 20,000 years ago, winds deposited loess south of the glacial boundary including the Indian Creek watershed. Upland areas of this unglaciated area then are today covered with this wind deposited material while stream valleys are filled with glacial outwash and lake sediments from the melting glacier.

A. Subterranean Cut-Off

The drainage basin of Indian Creek offers a number of interesting physiographic phenomena. Indian Creek from its source in western Monroe County southwest of Bloomington to its entrance into East Fork White River a few miles above Shoals in Martin County traverses a sinuous route of approximately 43 miles in length, though the straight-line distance is approximately 28 miles. The valley in the upper portion is rather broad and lies on a limestone plain, which is perched from 100 to 150 feet above the more deeply intrenched streams on either side of the basin. This condition of its upper portion has resulted in wholesale subterranean "piracy", and some 15 square miles in area have been diverted from the surface route through Indian Creek to the more deeply intrenched streams on either side. Much of the former headwater region of Indian Creek is now drained by subterranean streams rather than by surface runoff. The Mitchell Plain west of Bloomington is pockmarked by numerous sinkholes. When the streams flowing across the broken or "clastic" rocks of the upland encounter the jointed dense limestone beds that characterize the karst plain they become "pirated" or captured by subterranean drainage. As more and more of the drainage goes underground, the stream ceases to carry any water over its course except during storms.

In the middle and lower portions of Indian Creek basin the valley is very rugged and narrow. It is deeply set in a dissected plain, the narrow valley floor lying from 200 to 300 feet below the preserved portions of the dissected plain. The upper parts of the valley sides are composed of clastic rocks belonging to the Chester series. These rocks often form benches with abrupt sides of massive sandstone facing the valley. The lower parts of the valley sides are composed of the Mitchell limestone, which is exposed in the steep, wall-like sides of the meander curves. Within the meander curves of the valley occur local sinkhole plains far below the dissected surface of the plain in which the valley is cut. Springs of considerable size enter the stream and furnish a large part of the perennial waters. Some of these springs are mineral springs, such as Trinity Springs and Indian Springs in Martin County. At one place a complex meander curve more than 3 miles in length is in the process of being cut off through the development of subterranean drainage beneath the spur of upland across the narrow neck of the meander loop.

Subterranean drainage takes place as a matter of economy of distance. The subterranean routes are always shorter and more direct than the abandoned surface routes. In the case of Possum Valley the economy of distance is obvious. The subterranean route under the dividing ridge is very short as compared to the old surface route below. Streamless valleys of this sort may have one or more than one underground system, but the old surface stream is broken up onto a large number of small surface systems. Each tributary of the former surface stream may become a small surface system to itself, possessing its own particular swallow hole marking the terminus of the individual surface system.

B. Springs

Trinity Springs, so called from their number, are among the oldest and best known "sulphur springs" of the State, are located in the northwest quarter of Section 28 of T4N, R3W. Less than two miles to the northwest is Indian Springs where water from a vein a few feet below the surface, wells up at four different places within a few yards of one another on the west bank of Sulphur Creek, west half of Section 17, T4N, R3W.

The region is a short distance (two miles) north of the junction of Indian Creek with the East Fork of White River. Sulphur Creek joins Indian Creek just south of the center of the area.

These two streams are fed by springs and flow throughout the year. Physiographically the region is located in the driftless area a few miles east of the glacial boundary in southwestern Indiana. It is wholly within the Crawford upland, which constitutes the most rocky and rugged physiographic division in southern Indiana. Geologically the region is located along the boundary zone of the Mississippian and Pennsylvanian formations. It is with respect to the features pertaining to the boundary that the region is especially interesting topographically and geologically.

The Indian and Trinity Springs locality is in the rugged Crawford upland of southwestern Indiana. In general the upland ridges in the inter-valley areas of northern Martin County range from 700 to 800 or slightly more in altitude. Some ridges adjacent tot he major streams have been unevenly reduced below the common altitude. A careful analysis of the topographic condition of the region indicates that the upland divides are remnants of an old erosion surface reduces to a relatively low relief in which the inter-stream areas were rarely more than 100 feet above the very broad valleys of the main streams. The common level of the old valleys if restored would be at present about 700 feet above sea level.

The Trinity Springs issue from three places about which a cement platform has been constructed. A bluff of the Sample sandstone rises 15 or 20 feet above the cement platform on the north. A ravine that is usually dry enters from the east. Nothing in the sandstone rock, which swings nearly half around the springs, suggests faulting. The springs issue at or near the expected horizon of the Beaver Bend limestone.

The Indian Springs issue from at least five individual openings. Three of them are practically in the bed of Sulphur Creek just north of the bridge on the west side of Indiana Springs Hill. The other two are northeast about 50 and 75 yards and line up directly with the three just north of the bridge. They are located in the low flood plain about 20 yards from the steep bluff of Indian Springs Hill and issue as boiling springs directly out of shallow depressions. The line of five springs extends northeast southwest. Their alignment suggests the possibility that they occur along a fault. They occur between tow outcrops of the Beaver Bend limestone which are about 200 yards apart and which show about 15 feet difference in elevation.

The depths from which the highly mineralized waters of both Indiana and Trinity Springs originate are unknown. The up-rising highly mineralized waters very likely are associated with the underlying middle Mississippian limestones, somewhat similar to the springs in the low valleys at French Lick and West Baden where the topographic and geologic conditions are nearly identical.

5. Soils

The topography of the Indian Creek watershed consists of lowlands separated by generally rugged upland areas. The watershed area is part of, and along the east edge of, the Crawford Upland physiographic unit. East of this area the topography changes rather abruptly to the Mitchell Plain, which has some of the best-developed karst topography in the world.

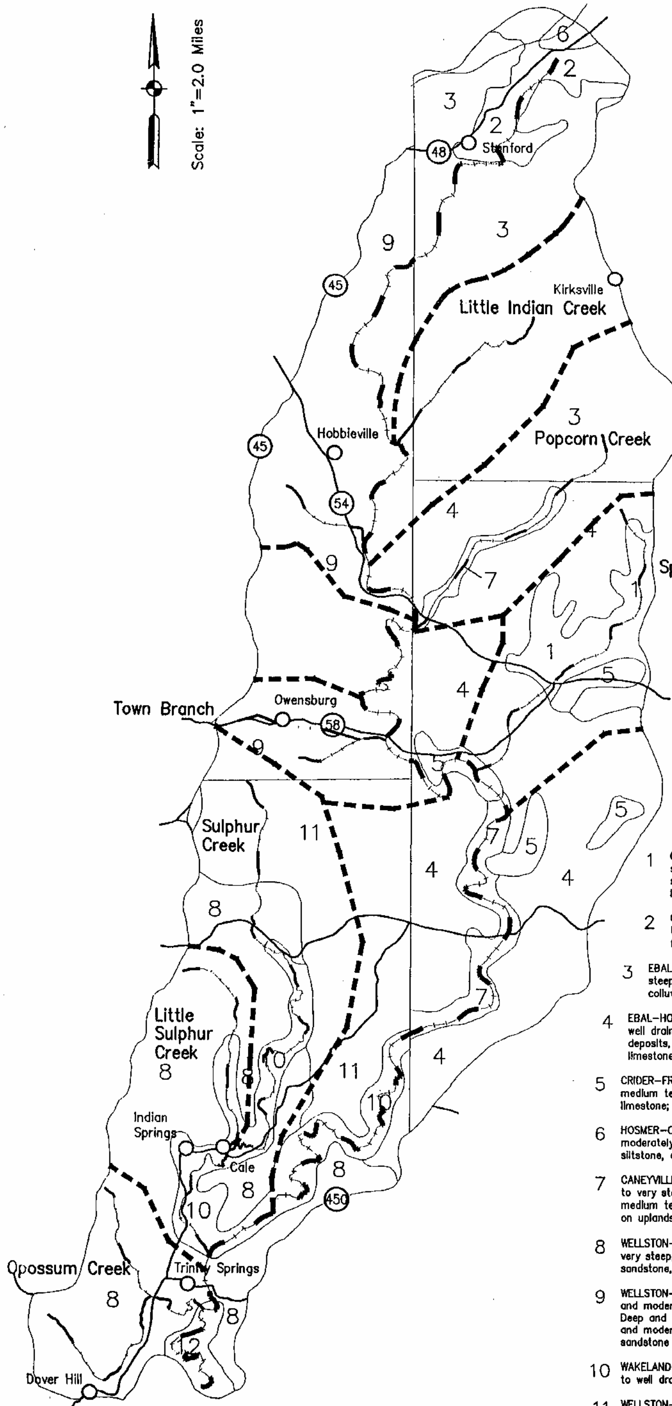

Figure II-1

Indian Creek Watershed Project

General Soils Map

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1 CRIDER–FREDERICK–BEDFORD: Deep, Gently sloping to strongly sloping, well drained and moderately well drained, medium textured soils that formed in loess and the underlying residuum from limestone; on uplands.

2 CRIDER–CANEYVILLE: Deep and moderately deep, gently sloping to strongly sloping, well drained soils formed in loess and residuum from limestone; on uplands.

3 EBAL–GILPIN–TILSIT: Deep and moderately deep, nearly level to moderately steep, moderately well drained and well drained soils formed in loess, colluvium, and residuum from shale, sandstone, and siltstone; on uplands.

4 EBAL–HOSMER–CRIDER: Deep, gently sloping to moderately steep, moderately well drained and well drained, medium textured soils that formed in loess deposits, or in loess or colluvium and the underlying residuum from sandstone, limestone, or shale; on uplands.

5 CRIDER–FREDERICK: Deep, moderately sloping and strongly sloping, well drained, medium textured soils that formed in loess and the underlying residuum from limestone; on uplands.

6 HOSMER–CRIDER: Deep, nearly level to moderately sloping, well drained and moderately well drained soils formed in loess and residuum from limestone, siltstone, and shale; on uplands.

7 CANEYVILLE–HAYMOND–STENDAL: Moderately deep and deep, moderately sloping to very steep and nearly level, well drained and somewhat poorly drained, medium textured soils that formed in limestone residuum or in silty alluvium; on uplands and flood plains.

8 WELLSTON–BERKS–GILPIN: Deep and moderately deep, gently sloping to very steep, well drained soils formed in loess and material weathered from sandstone, siltstone, and shale on uplands.

9 WELLSTON–ZANESVILLE–GILPIN: Very gently sloping to very steep, well drained and moderately well drained soils on uplands.
Deep and moderately deep, very gently sloping to very steep, well drained and moderately well drained; medium textured soils formed in loess and in sandstone and shale residuum; on uplands.

10 WAKELAND–WILBUR–HAYMOND: Deep, nearly level, somewhat poorly drained to well drained soils formed in alluvium on bottom land.

11 WELLSTON–BERKS–EBAL: Deep and moderately deep, gently sloping to very steep, well drained and moderately well drained soils formed in loess and material weathered from sandstone, siltstone, and shale on uplands.

12 NEWARK–WIRT–NOLIN: Deep, nearly level, somewhat poorly drained and well drained soils formed in alluvium on bottom land.

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The watershed includes generally wide ridge tops and many natural features including caves, cliffs, and overhangs.

Also common to the Crawford Upland area are mineral and freshwater springs. The area is underlain by alternating layers of sandstone, shale, and limestone that have been eroded to produce upland areas with diverse topographic features. Drainage patterns are generally well developed with narrow, flat divides and valley walls are steep. The bottoms of the large valleys are moderately wide flood plains and are usually the only level lands found in the area.

A. Soil Associations

A General Soil Map of soil associations is presented as Figure II-1. A general description, by county, is included with the map. County in the succeeding paragraphs further discusses these various soil associations.

1. Martin County

Four soil associations are represented in the portion of the watershed found in Martin County. The Wellston-Berks-Gilpin map unit is on ridge tops and side slopes in upland areas. Areas are relatively large and are separated by long, narrow bottomland and ridges. These soils are deep to moderately deep, gently sloping to very steep and are well drained having been formed in loess and material weathered from sandstone, siltstone, and shale. Another soil association represented is the Wellston-Berks-Ebal association, which is very similar. A noted exception is the inclusion of more soils, which are moderately well drained especially the Ebal silt loam soil.

The Wakeland-Wilbur-Haymond association consists of deep, nearly level, somewhat poorly drained to well drained soils formed in alluvium on bottomlands. This map unit is found on broad bottomlands along meandering sections of Indian Creek. The Newark-Wirt-Nolin soil association also consists of deep, nearly level, somewhat poorly drained and well-drained soils that were formed in alluvium on bottomlands. This association, however, is confined to areas along the White River.

2. Lawrence County

There are four separate soil associations identified in the Indian Creek watershed area, which occur in Lawrence County. The Ebal-Hosmer-Crider association has deep, gently sloping to moderately steep, moderately well drained and well-drained, medium textured soils. These soils formed in loess deposits, or in loess or colluvium and the underlying residium from sandstone, limestone, or shale. This association is found in upland settings of the landscape. This map unit is a dissected plain on which the main divides are broad, rounded ridge tops. The stream bottoms are broad and the hillsides are moderately sloping to moderately steep. Some drainageways start on the hillsides and disappear into sinkholes when they reach the valley floor.

The Crider-Frederick-Bedford association is deep, gently sloping to strongly sloping, well drained and moderately well drained. These medium textured soils formed in loess and the underlying residuum from limestone and are also found in upland areas. This map unit is generally a loess covered plain on the uplands that contain some sinkholes and some dissected areas along the drainageways. There are a few sinkholes into which drainageways disappear throughout the area.

The Crider-Frederick association is deep, moderately sloping and strongly sloping, well-drained soils that are medium textured. These soils are on uplands and formed in loess and the underlying residuum from limestone. This map unit is a karst or sinkhole region found at the transition from the Crawford Uplands to the Mitchell Plains. The topography was originally gently sloping or moderately sloping, but the landscape now has many large sinkholes. Because of the limited surface drainage system, surface water must drain internally through underground passageways that connect a series of sinkholes. This network of passageways is very complex and their exact locations are not known.

The Caneyville-Haymond-Stendal soil association has soils that are moderately deep-to-deep and are moderately sloping to very steep to nearly level. The soils are well drained to somewhat poorly drained medium textured soils that formed in limestone residuum or in silty alluvium. This map unit includes soils formed on uplands and floodplains along the broad bottomlands of Indian Creek and Popcorn Creek.

3. Greene County

The entire Indian Creek watershed found in Greene County involves soils of the Wellston-Zanesville-Gilpin association. These soils are described as deep and moderately deep, very gently sloping to very steep medium textured soils. They are well drained and moderately well drained and were formed in loess and in sandstone and shale residuum on uplands. This map unit consists of soils on ridge tops, on side slopes, and in draws. Areas are deeply dissected by Indian Creek and smaller tributaries, which are bordered by narrow bottomland. Areas are generally large and irregularly shaped.

4. Monroe County

The Indian Creek watershed area of Monroe County includes three general soil map associations. The Ebal-Gilpin-Tilsit unit has soils that are deep and moderately deep and are nearly level to moderately steep. The soils are moderately well drained to well drained that were formed in loess, colluvium, and residuum from shale, sandstone, and siltstone generally on uplands. This map unit is a single large area, which is a dissected plain having main divides that are broad, rounded ridge tops. The bottoms along Indian Creek and Little Indian Creek are broad and the hillsides are moderately sloping to moderately steep. A few drainageways begin on the hillsides and disappear into sinkholes when they reach the valley floor.

The Crider-Caneyville soil association is found near and upgradient of Stanford in Monroe County. Soils are deep to moderately deep and range from nearly level to moderately steep.

They are moderately well drained to well-drained soils that were formed in loess, colluvium, and residuum from limestone on upland areas. These areas are characterized mainly by a rolling plain that has some sinkholes and some highly dissected areas along Indian Creek.

At the extreme top of the Indian Creek watershed is the Hosmer-Crider soil association. These soils are deep, nearly level to moderately sloping soils. The soils are well drained to moderately well drained and were formed in loess and residuum from limestone, sandstone, siltstone, and shale on uplands. This map unit is a single medium-sized area. It is mainly a loess covered upland plain that includes some sinkholes and some dissected land along drainageways leading to Indian Creek.

B. Hydric Soils

A hydric soil is a soil that is saturated, flooded, or ponded long enough during the growing season to develop anaerobic conditions. This lack of oxygen in the soil can lead to the formation of certain observable characteristics in wetland soils, such as a thick layer of organic matter (non-decomposed plant materials) in the upper part of the soil column. Other observable features include oxidized root channels and redoximorphic features (concentrations and depletions of Iron and other elements, i.e., mottling, gleying).

Based on an analysis of the hydric soils mapped in the soil surveys of the four counties and located in the Indian Creek watershed, there were approximately 2,890 acres of wetlands in the Indian Creek watershed 200 years ago. Refer to Section IV-1 for a detailed discussion of hydric soils in the watershed and the associated wetland losses.

C. Highly Erodible Land

These lands have been defined in order to identify areas on which erosion control efforts should be concentrated. The definition is based on Erosion Indexes derived from certain variables of the Universal Soil Loss Equation and the Wind Erosion Equation. The indexes are the quotient of tons of soil loss by erosion predicted for bare ground divided by the sustainable soil loss (T factor).

To mitigate soil erosion on highly erodible land (HEL), the 1985 Farm Bill introduced the Conservation Compliance and Sodbuster programs. These programs require farmers to implement approved soil conservation systems on land defined by USDA as highly erodible lands to receive certain USDA program benefits. In 1992, the USDA's Natural Resource Conservation Service (NRCS) designated 105 million acres, roughly one-third of total U.S. cropland, as HEL.

Highly Erodible Land (HEL) is land that has a soil erodibility index (EI) of 8 or more. The EI provides a numerical expression of the potential for a soil to erode considering the physical and chemical properties of the soil and the climatic conditions where it is located. The higher the index, the greater the investment needed to maintain the productivity of the soil if intensively cropped.

The majority of the soils in the Indian Creek Watershed are classified as highly erodible lands or at least potentially highly erodible lands (PHEL). In the future, digitized soil survey maps will provide opportunity for mapping these sensitive soil types at the county and watershed level. Published soil surveys for the four counties involved in the Indian Creek watershed were reviewed and correlated with NRCS Field Office Technical Guide information to summarize the presence of highly erodible lands in the watershed. Table II-3 presents that information.

Table II-3

County HEL Soils

Greene County

Map symbol	Soil Name	HEL Class	Acres	Percent of County
AIC2	Alford	1	760	0.2
BcF	Berks-Ebal	1	6,600	1.9
BfG	Berks-Rock outcrop	1	990	0.3
BIG	Bloomfield	1	560	0.2
CcE2	Chetwynd	1	2,100	0.6
CcF	Chetwynd	1	6,000	1.7
CfC3	Cincinnati	1	4,050	1.2
CfD2	Cincinnati	1	4,200	1.2
CfD3	Cincinnati	1	1,400	0 4
ChC2	Cincinnati	1	3,400	1.0
EcD	Ebal-Gilpin	1	1,000	0.3
EfD2	Ebal-Wellston	1	7,500	2.1
GcE2	Gilpin	1	2,000	0.6
GfF	Gilpin-Berks	1	6,500	1.9
GgE	Gilpin-Ebal	1	6,100	1.7
GmE	Gilpin-Wellston	1	20,750	6.0
HaE2	Hagerstown	1	570	0.2
HeD2	Hickory	1	2,150	0.6
HeE	Hickory	1	6,200	1.8
HeG	Hickory	1	2,850	0.8
PbD2	Parke	1	2,000	0.6
UnE	Uniontown	1	1,050	0.3
WeD2	Wellston	1	18,600	5.3
WeD3	Wellston	1	2,900	0.8
ZaC2	Zanesville	1	12,900	3.7
ZaC3	Zanesville	1	4,000	1.1
AIB2	Alford	2	1,850	0.5
AnC	Alvin-Bloomfield	2	2,900	0.8
AvB2	Ava	2	31,685	9.2
BIE	Bloomfield	2	1450	0.4
CfC2	Cincinnati	2	10,200	2.9
HdA	Henshaw	2	1,150	0.3
MbB2	Markland	2	500	0.1
MgA	McGary	2	600	0.2
PbC2	Parke	2	1,000	0.3
PdB2	Pekin	2	2,150	0.6
PkB2	Pike	2	3,700	1.1
PkC2	Pike	2	2,600	0.7
PrB	Princeton	2	2,400	0.7
PrC	Princeton	2	1,200	0.3
ScA	Shakamak	2	9,700	2.8
WgD2	Wellston	2	1,000	0.3
ZaA	Zanesville	2	470	0.1
ZaB2	Zanesville	2	11,500	3.3
	Subtotal	1	127130	36.1
	Subtotal	2	86,055	24.6
	Total		**213185**	**60.7**

Table II-3 (Con't)
County HEL Soils

Lawrence County

Map symbol	Soil Name	HEL Class	Acres	Percent of County
AnD	Alvin	1	2,563	0.9
CcC2	Caneyville	1	3,472	1.2
CcD2	Caneyville	1	13,536	4.6
CfF	Caneyville-Gilpin	1	12,543	4.3
CrD2	Crider	1	1,932	0.7
CsD2	Crider-Caneyville	1	10,064	3.4
EbC2	Ebal	1	3,974	1.4
EdD	Ebal-Wellston	1	13,467	4.6
FrD	Frederick	1	8,293	2.8
FtD3	Frederick	1	2,173	0.7
GwF	Gilpin-Weikert	1	12,186	4.1
PeC2	Pekin	1	923	0.3
WbF	Weikert-Berks	1	26,637	9.1
WeC2	Wellston	1	4,667	1.6
WeD2	Wellston	1	5,857	2.0
WfD3	Wellston	1	1,761	0.6
WgD2	Wellston-Gilpin	1	5,839	2.0
BdB2	Bedford	2	16,070	5.5
BmC	Bloomfield	2	2,607	0.9
Bu	Burnside	2	6,652	2.3
CrB	Crider	2	10,062	3.4
CrC2	Crider	2	32,699	11.0
CwD2	Crider-Frederick	2	27,365	9.3
EkB2	Elkinsville	2	551	0.2
FrC2	Frederick	2	4,330	1.5
FwC2	Frederick-Crider	2	11,041	3.8
GrC	Gilpin-Crider	2	4,310	1.5
Ho	Haymond	2	7,703	2.6
HrA	Henshaw	2	1,048	0.4
HxB2	Hosmer	2	5,265	1.8
MdB2	Markland	2	1,068	0.4
MhA	McGary	2	1,542	0.5
PeB	Pekin	2	1,290	0.4
PnB	Princeton-Alvin	2	997	0.3
TyB	Tyner-Alvin	2	821	0.3
	Subtotal	1	129,887	44.3
	Subtotal	2	135,421	46.1
	Total		**265,308**	**90.4**

Table II-3 (Con't)
County HEL Soils

Martin County

Map symbol	Soil Name	HEL Class	Acres	Percent of County
AvE	Alvin-Chelsea	1	1,350	0.6
HaD	Hagerstown	1	280	0.1
PaD2	Parke	1	450	0.2
WeD2	Wellston	1	9,100	4.2
WeD3	Wellston	1	5,200	2.4
WgG	Wellston-Berks	1	75,000	34.4
WlD	Wellston-Ebal	1	4,000	1.8
WnE	Wellston-Gilpin	1	36,000	16.5
WpD	Wellston-Udorthents	1	1,210	0.6
ZaC2	Zanesville	1	10,000	4.6
ZaC3	Zanesville	1	2,650	1.2
ZnC	Zanesville-Udorthents	1	2,300	1.1
AvC2	Alvin-Chelsea	2	1,750	0.8
CaB	Camden	2	780	0.4
CnB	Cincinnati	2	260	0.1
CrC	Crider	2	130	0.1
HoB	Hosmer	2	3,500	1.6
MaB	Markland	2	1,150	0.5
McC3	Markland	2	470	0.2
MgA	McGary	2	380	0.2
NeE	Negley	2	790	0.4
PaC2	Parke	2	520	0.2
PeB	Pekin	2	580	0.3
PkB	Pike	2	500	0.2
WeB	Wellston	2	910	0.4
WeC2	Wellston	2	10,900	5.0
ZaB	Zanesville	2	10,700	4.9
ZnB	Zanesville-Udorthents	2	1,050	0.5
	Subtotal	1	147,540	67.7
	Subtotal	2	34,370	15.8
	Total		**181,910**	**83.5**

Table II-3 (Con't)
County HEL Soils

Monroe County

Map symbol	Soil Name	HEL Class	Acres	Percent of County
BdB	Bedford	1	7,680	2.9
BkF	Berks-Weikert	1	64,833	24.6
CaD	Caneyville	1	15,730	6.0
Cb	Caneyville-Hagerstown	1	2,435	0.9
ChF	Chetwynd	1	1,790	0.7
CoF	Corydon-Caneyville	1	3,320	1.3
CrB	Crider	1	6,205	2.4
CrC	Crider	1	31,630	12.0
CrD	Crider	1	840	0.3
CsC	Crider-Caneyville	1	1,730	0.7
CtB	Crider-Urban	1	1,965	0.7
CtC	Crider-Urban	1	4,210	1.6
EbE	Ebal-Gilpin	1	5,405	2.0
EdD	Ebal-Wellston	1	10,175	3.9
EkF	Elkinsville	1	2,835	1.1
GpD	Gilpin	1	790	0.3
GrD	Gilpin-Gullied	1	230	0.1
HaC	Hagerstown	1	825	0.3
HaD	Hagerstown	1	5,505	2.1
HaE	Hagerstown	1	300	0.1
HbD3	Hagerstown	1	285	0.1
Hc	Hagerstown-Caneyville	1	1,960	0.7
HkF	Hickory	1	2,040	0.8
HoC	Hosmer	1	2,180	0.8
HtB	Hosmer-Urban	1	635	0.2
PaC	Parke	1	850	0.3
PcD	Parke-Chetwynd	1	530	0.2
PeB	Pekin	1	1,380	0.5
PeC	Pekin	1	725	0.3
PrC	Princeton	1	135	0.1
PrE	Princeton	1	230	0.1
RcB	Ryker	1	495	0.2
RcC	Ryker	1	1,410	0.5
RcD	Ryker	1	610	0.2
TlB	Tilsit	1	3,855	1.5
WeC	Wellston	1	4,590	1.7
WmC	Wellston-Gilpin	1	16,370	6.2
ZnC	Zanesville	1	1,785	0.7
AfB	Alford	2	900	0.3
Ba	Bartle	2	1,532	0.6
EkB	Elkinsville	2	685	0.3
HoB	Hosmer	2	4,575	1.7
MbB	Martinsville	2	230	0.1
PaB	Parke	2	480	0.2
	Subtotal	1	208,498	79.1
	Subtotal	2	8,402	3.2
	Total		**216,900**	**82.3**

In the tables, the HEL classification of 1 refers to highly erodible soil while a value of 2 in this column identifies a soil map unit that is potentially highly erodible. Table II-4 summarizes the totals and proportions from the four counties involved. Without digitized soil maps, it is beyond the scope of this study to map or accurately quantify the HEL acreage for the watershed. A correlation can be derived however based on the percentage HEL acreage in each county and the acreage of the county that occurs in the watershed

Table II-4
HEL Acreage in Indian Creek Watershed

County	Greene	Lawrence	Martin	Monroe	Total
Acres in watershed	19900	31400	36200	22500	110000
% Of County that is HEL	60.7	90.4	83.5	82.3	
HEL acreage in watershed (Assumes equal distribution of HEL acreage throughout county)	12079	28386	30227	18518	89209
% Of Indian Creek watershed that is HEL					81.1

6. Climate

In the Indian Creek watershed, summers are generally hot in the valleys and slightly cooler in the hills. Winters are moderately cold. Rains are fairly heavy and are well distributed throughout the year. Snow falls every winter; however, the snow cover typically lasts only a few days. Winter precipitation results in a good accumulation of soil moisture by spring and this minimizes drought on most soils during most summers.

The normal annual precipitation is approximately 43 inches, which is adequate for all of the crops that are suited to the temperature and growing season of the area.

7. Sensitive Areas & Critical Habitats

Information on critical habitats, unique natural areas, and protected species was obtained from the IDNR Division of Nature Preserves. Protected species include those categorized as: extirpated (abolished), endangered, threatened, rare, special concern, watch list, significant, or state reintroduced on the state level.

Tables II-5 and II-6 present the protected species of concern and their categories.

Table II-5
Protected Species
found in the
Indian Creek Watershed

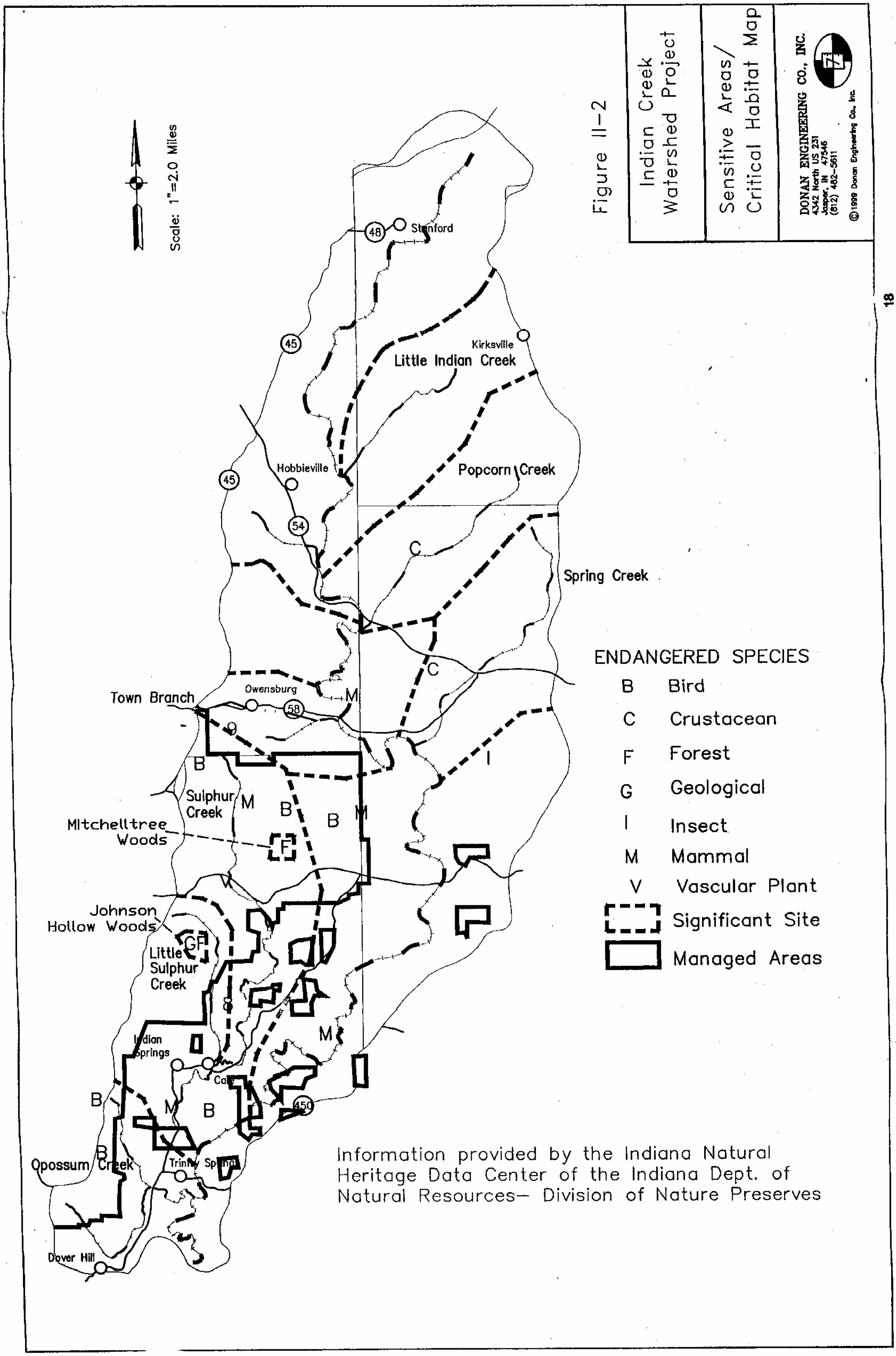
Type	Species	Common Name	Status
Mammal	Lynx rufus	Bobcat	Endangered
Bird	Ammodramus herodias	Henslow's sparrow	Endangered
Plant	Glyceria acutiflora	Sharp-scaled manna-grass	Endangered
Mammal	Myotis sodalis	Indiana bat	Endangered
Insect	Pseudanophthalmus leonae	Cave beetle	Endangered
Insect	Pseudanophthalmus shilohensis	Cave beetle	Endangered
Plant	Carex straminea	Straw sedge	Threatened
Plant	Trichostema dichotomum	Forked bluecurl	Rare
Bird	Buteo lineatus	Red-shouldered hawk	Special Concern
Bird	Buteo platypterus	Broad winged hawk	Special Concern
Bird	Helmitheros vermivorus	Worm-eating warbler	Special concern
Bird	Mniotilta varia	Black-and-white warbler	Special concern
Bird	Wilsonia citrina	Hooded warbler	Special Concern
Bird	Dendroica cerulea	Cerulean warbler	Special Concern
Plant	Juglans cinerea	Butternut	Watch List
Bird	Ardea herodia	Great Blue Heron	Not listed
Crustacean	Orconectes inermis	A troglobitic crayfish	Not listed
Caddisflies	Agapetus illini	An Agapetus caddisfly	Not listed

The Agapetus caddisfly, though shown in the "Not listed" status, is specifically adapted to spring systems and has only been collected in Indiana from Indian Creek in Springville in 1946. Those performing future monitoring should be aware of the potential for finding and reporting this or similar organisms.

Table II-6
High Quality Plant Communities
found in the
Indian Creek Watershed

Name	Feature	Status
Johnson Hollow Woods Natural Area	Dry upland forest	Significant
"	Dry-mesic upland forest	Significant
"	Mesic upland forest	Significant
"	Sandstone Cliff	Significant
Mitchelltree Woods Notable Area	Dry-mesic upland forest	Significant
"	Mesic upland forest	Significant

Refer to Figure II-2 for a map of the locations of these observations.



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III. HISTORICAL DATA

1. Overview

The data available for characterizing the water quality of Indian Creek in the past is found to be limited and diverse. There have been attempts to monitor water quality by various groups and, in some instances; the monitoring has been repeated for significant durations and frequencies. For the most part however, these efforts of the various groups have been dispersed well along the stream to the extent that they are generally unrelated. The historical data includes Indiana Department of Environmental Management (IDEM) data, volunteer monitoring by an Eastern Greene High School group, and fisheries surveys by the Indiana Department of Natural Resources- Division of Fish & Wildlife and others.

2. Fisheries Reports

The fishery of Indian Creek is monitored by the Indiana Department of Natural Resources-Division of Fish & Wildlife. Indiana DNR reports that the East Fork of White River near the confluence with Indian Creek is known to contain one of the last reproducing populations of the endangered Lake Sturgeon (*Acipenser fulvescens*) in the Ohio River basin. District fisheries biologists have identified Indian Creek as a significant small mouth bass fishery, although this fishery is reportedly diminishing in the lower third of Indian Creek in the past few years

A. 1978 Research Report

An evaluation of the effects of night spear fishing on sport fishing and the environment was completed by Fisheries Biologist Robert L. Ball of the Fisheries Section of the Division of Fish & Wildlife. To evaluate the effect of indiscriminate night spear fishing on fish populations of small streams, four spear fishing and two control sites were established in 1978 on streams in Lawrence County, Indiana. Sites on Indian Creek and Guthrie Creek were selected for riffle and shallow pool habitat. Spring Creek, a tributary of Indian Creek and a smaller stream, was selected for its variety of habitat.

Spear sites were spear fished in April and May with catch and effort information recorded. In May and early June the fish at all sites were sacrificed with Rotenone and collected for standing crop estimates. Some spear fishing continued into September.

The presence of clear water and spawning concentrations of food fishes were regarded as the most important factors in determining spear fishing success. Sunfishes were the most easily speared game fishes and they could readily be distinguished from food fishes. Small mouth and largemouth bass tended to stay in deeper water, making them harder to spear. Typically they could be distinguished from food fishes by their dark pectoral fins.

Standing crop estimates of up to eight pounds/acre of small mouth bass were found at spear sites after two months of spear fishing. Spear fishing did not appear to have been a great factor in limiting small mouth bass standing crops. Rock bass populations were affected by spear fishing in the clearest stream site (Spring Creek) but apparently were not seriously affected at the other sites. Standing crops of food fishes averaged 46 pounds/acre, versus 21 pounds/acre for game fishes. The average total standing crop was 92 pounds/acre.

An average catch rate of 2.5 food fish/hour (3.0 pounds/hour) was obtained for the period of April 4 through September 29. The April through May catch rate was even higher; 2.6 fish and 3.3 pounds/hour. A harvest of 46 pounds/acre of food fishes was taken during the April to September period. Of that, 90% were speared in April and May when food fishes were in spawning concentrations. The most important species in the harvest were shorthead redhorse, spotted sucker, northern hog sucker, and carp. The harvest did not appear to have a detrimental effect on the fish communities.

B. 1990 Report

A study was performed by AQUATIC ECOSYSTEMS, to assess aquatic species populations, on tributaries of the East Fork White River in Greene and Monroe Counties. Known tributaries include First, Bogard, Doane, Plummer, Black Ankle, Beech, Bridge, Indian, and Clear Creeks. Multiple stations were established at each creek and Indian Creek had four stations. Only excerpts of this report were available to Donan Engineering, and the available information is presented in tabular form as Table III-1 on the next page.

Table III-1
Aquatic Ecosystems
Report Summary

	Stations				
	19	20	21	22	23
Location					
Quad	Owensburg	Stanford	Stanford	Stanford	Stanford
County	Greene	Greene	Monroe	Monroe	Monroe
Section	1	36	6	32	28
Township	6N	7N	7N	8N	8N
Range	3W	3W	2W	2W	2W
Quarters	NWNENW	NWSWNE	SESENW	SWNWSW	NENENW
Road Crossing	1325 East	1375 West	Breeden Rd.	1500 East	1650 East
Features					
Width (Ft)	20-25	6-25	10-15	10-20	3-8
Depth (Ft)	0.5-2	0.5-1.5	0.5-1	0.3-3	0.3-1.5
Velocity	Yes	Very Slight	Slight	Good	Slight
Insects	Mayflies, Caddisflies, Helgramites	Mayflies, Caddisflies, Helgramites, Water Pennies	Mayflies, Water Pennies	Mayflies, Stoneflies, Caddisflies, Helgramites, Water Pennies	Water stridders
Other Organisms	Snails, Crayfish	Bullfrog, Clam, Snails, Crayfish	Crayfish, Snails, Horsetails	Crayfish, Snails	Snails, Clam
Fish Species					
Small mouth Bass				1	
Creek Chub	37	27	1	11	2
Fantail Darter	6	6		8	2
Greenside Darter	16	1	3	2	
Johnny Darter			2		1
Rainbow Darter	13	2		4	7
Bluntnose Minnow		1	21	10	3
Silverjaw Minnow		1			
Suckermouth Minnow					3
Banded Sculpin	1			1	
Mottled Sculpin	1				
Emerald Shiner	19		13		
Redfin Shiner		26		3	
Striped Shiner	2	25	30	55	9
Silver Shiner		5			
Hog Sucker		1			
Stoneroller	5	1	7	17	

C. 1994 Fish Management Report

The FISHERIES SURVEY OF LOWER INDIAN CREEK was prepared by Fisheries Biologist Steven J. Andrews of the Indiana DNR- Division of Fish & Wildlife. This survey targeted the 15-mile stretch of lower Indian Creek in Martin County. The survey was conducted as part of a work plan entitled "A survey of fish communities and aquatic habitats at Indiana's major streams with emphasis on small mouth bass distribution and abundance." This work plan included work on streams with a mean discharge of 100 cfs or greater. Lower Indian Creek exceeds this level of discharge but the upper and middle reaches do not.

Two stations were sampled. One was 4.5 river miles upstream of the confluence with East Fork White River while the other was 13 miles upstream.

The survey was conducted May 23 and 24, 1994. As required by the work plan, repeat sampling for small mouth bass was conducted September 8 and 12, 1994. Work plan objectives as they applied to this survey were to:

1) determine the distribution and abundance of small mouth bass in lower Indian Creek,
2) determine the relationship of habitat conditions to small mouth bass distribution and abundance,
3) determine fishing opportunities for other species and the presence of nongame species, and
4) assess aquatic habitats to aid in future environmental assessments.

A total of 1,073 fish weighing 306.45 pounds was collected in May. Both samples combined included 45 species from 13 families represented. Table III-2 summarizes the results.

Table III-2
Lower Indian Creek
1994 Fish Management Report

Family	Species Included	Number	%	Weight	%
Herrings	Gizzard shad	388	36.2	69.44	22.7
Sunfishes	Longear sunfish, spotted bass, bluegill, rock bass, warmouth, green sunfish, small mouth bass, largemouth bass	165	15.4	132.86	43.4
Suckers	Spotted sucker, golden rehorse, black redhorse, river carpsucker, small mouth buffalo, shorthead redhorse, bigmouth buffalo, silver redhorse, quillback, northern hog sucker, highfin carpsucker	165	15.4	132.86	43.4
Carps & Minnows	Emerald shiner, steelcolor shiner, spotfin shiner, bluntnose minnow, common carp, golden shiner	110	10.3	21.9	7.1
Drums	Freshwater drum	34	3.2	25.59	8.4
Perches	Blackside darter, greenside darter, sauger, dusky darter, Johnny darter, logperch, slenderhead darter, fantail darter	34	3.2	3.55	1.2
Mooneye	Mooneye	7	0.7	2.3	0.8
Gars	Longnose gar, shortnose gar	5	0.5	4.92	1.6
Bullhead catfishes	Channel catfish, flathead catfish, brindled madtom	3	0.3	8.54	2.8
Pikes	Grass pickerel	2	0.2	0.36	0.1
Freshwater eels	American eel	1	0.1	2.19	0.7
Bowfins	Bowfin	2	-	9.47	-
Sculpins	Banded sculpin	1	-	0.01	-

Water quality data suggests that lower Indian Creek experiences some oxygen depletion during late summer and early fall. Overall, water quality appeared to be satisfactory for a warm water fish population. Fish habitat at each station was evaluated using the Qualitative Habitat Evaluation Index (QHEI). Component scores were higher for nearly all categories at the upstream station however, it is reported, and the primary reason for the higher score was riffle habitat. Table III-3 presents the component scores for the two stations. A total score of 60 or more indicates the stream segment is suitable for warm water habitat without use impairment.

Table III-3
QHEI Metric Component Scores
for two stations on
Indian Creek

River Mile	Substrate	Instream Cover	Channel Morphology	Riparian Zone	Pool Quality	Riffle Quality	Gradient	Total Score
4.5	10	13	16	7.5	12	6	6	70.5
13.0	10	12	13	5	10	0	6	56

The report concludes indicating Indian Creek is known to provide fair to good fishing opportunities in the middle and upper reaches of the stream. Overall, sport-fishing opportunities on lower Indian Creek appear to be only fair at best.

D. 1998 Fish Management Report

The EVALUATION OF GAME FISH POPULATIONS IN INDIAN CREEK report was prepared by Assistant Fisheries Biologist Brian M. Schoenung of the Division of Fish & Wildlife. The survey includes population estimates of game species in the middle stretch of Indian Creek. The study was conducted as part of a work plan entitled "Evaluation of game fish populations and recreational uses on Indiana streams."

Population estimates for game fish were conducted at four separate stations. Sampling was conducted on June 2 and 3, 1998 on the upper two stations and July 12 and 14, 1998 on the lower two stations. This survey addressed the first of three objectives in the work plan.

1) Conduct population estimates for small mouth bass and other dominant game fish in 1998 and 2004.
2) Collect catch per effort data on the dominant game species during spring and fall in 2000 and 2002.
3) Conduct a general fish community survey during one of the two sampling events conducted in 2000.

Three stations were sampled in Greene County and one in Lawrence County. Population estimates were obtained by using the removal method. A computer software program for generating population statistics from electrofishing data was used to create population estimates based on a descending removal pattern.

The number of fish collected at these stations is presented in Table III-4.

Table III-4
Fish Management Report
1998
Summary

	Station					
	1	2	3	4		
Location						
Quad	Owensburg	Owensburg	Owensburg	Owensburg		
County	Greene	Greene	Greene	Lawrence		
Section	36	13	36	8		
Township	7N	6N	6N	5N		
Range	3W	3W	3W	2W		
Quarters	NESE	SWSE	SENE	NWNE		
Average Annual Flow (CFS)	35.0	62.7	77.4	94.2		
Fish Species					Total	%
Small mouth Bass	23	29	7	11	70	17.5
Spotted Bass	5	6	8	7	26	6.5
Rock Bass	123	40	45	90	298	74.5
Largemouth Bass	-	-	6	-	6	1.5

Scale samples were collected separately from each station to determine if differences in growth existed. Growth data was combined and compared to average back-calculated lengths for the ecoregion when it was determined that growth was similar between stations. Indian Creek is located in the Interior Plateau ecoregion. Growth data for this ecoregion was compiled as part of a statewide small mouth bass/stream fish community inventory. However most of the stream data was from streams with average flows greater than 100 cfs. The four stations in this survey were well below 100 cfs.

Indian Creek small mouth bass back-calculated lengths were approximately 0.8 inches below the average for the interior plateau ecoregion. Growth of spotted bass, rock bass, and largemouth bass was also below the interior plateau average, however, this below average growth, it is reported, may be attributed to the relatively small size of the stream. A table correlating length at age data for Indian Creek with the interior plateau ecoregion was presented in the report and is duplicated below.

Table III-5
Indian Creek game fish average back-calculated lengths at age 1998.
Interior Plateau ecoregion averages for comparison.

Fish Species		Length at age							
		1	2	3	4	5	6	7	8
Small mouth bass	Indian Creek	3.2	5.7	8.1	9.9	11.7			
	Interior Plateau	4.0	6.5	8.9	10.6	13.0	15.0		
Spotted bass	Indian Creek	2.3	4.7	7.1	8.9				
	Interior Plateau	3.0	6.1	8.5	10.7	12.1	12.8		
Rock bass	Indian Creek	1.8	2.8	4.1	5.5	6.6	7.2	7.7	8.5
	Interior Plateau	2.0	3.4	5.2	6.7	7.4	7.7		
Largemouth bass	Indian Creek	2.8	5.9						
	Interior Plateau	4.7	8.7	12.1	14.5				

A total of 70 small mouth bass were collected from the four stations. Most of these were collected in the upper two stations even though the stream was larger at the lower two stations. Fish habitat was similar between the four stations and would appear to be an unlikely limiting factor. Time of sampling and possibly higher fishing pressure at the lower two stations are cited as possible explanations.

The catch rate for spotted bass was more uniform between stations than the small mouth bass but was lower than expected. Rock bass were the most abundant game fish at all four stations. A total of 298 rock bass were collected from the four stations. Only one rock bass was over 9.0 inches in length.

3. Volunteer Monitoring

Eastern Greene High School students through the Future Farmers of America (FFA) organization have performed volunteer monitoring of one station of upper Indian Creek. Under the direction of teacher/advisor Gary Heshelman, the group has monitored this station annually and their data from 1995 through 1999 has been compiled. Their data includes both a benthic macroinvertebrates assessment as well as water quality indexing. The monitoring station is located on the Stanford Quadrangle southeast of the County Road 35N bridge crossing of Indian Creek in the southeast quarter of the southeast quarter of Section 23, T7N, R3W, in Greene County.

Table III-6
Volunteer Monitoring
Eastern Greene FFA
Benthic Macroinverterbrates

Stream Conditions	10/19/95	10/17/96	4/17/97	10/16/97	4/20/98	4/20/99
Relative flow	Low	Low	Free flowing	Calm	Normal	Rapid
Velocity (meters/sec)	0.016	0.44	0.3	-	.076	3.0
Water Temperature	20	17	-	18	15	10
	Bioassessment Scoring					
Group1- Pollution Intolerant	1	2	4	4	4	28
Group 2- Fairly Pollution Intolerant	14	10	14	6	12	9
Group 3- Moderately Pollution Tolerant	9	3	3	3	3	0
Group 4- Pollution Tolerant	4	0	0	0	0	1
Group Score Totals	28	15	21	13	19	38
Number of Taxa	12	8	12	8	11	-
Assessment	2.33	1.875	1.75	1.625	1.727	-
Water Quality Rating	Good	Excellent	Excellent	Excellent	Excellent	Excellent

Water Quality Assessment Chart	
1.0-2.0	Excellent Water Quality
2.0-2.5	Good Water Quality
2.6-3.5	Fair Water Quality
over 3.5	Poor Water Quality

Table III-7
Volunteer Monitoring
Eastern Greene FFA
Water Quality Index

	Date											
Stream Conditions Relative flow	10/19/95 Low		10/17/96 Low		4/17/97 Free flowing		10/16/97 Calm		4/20/98 Normal		4/20/99 Rapid	
Velocity (meters/sec)	0.016		0.44		0.3		-		.076		3.0	
Water Temperature	20		17		-		18		15		10	
	Scoring											
	Q-value	%	Q-value	%	Q-value	%	Q-value	%	Q-value	%	Q-value	%
Dissolved Oxygen	82	13.9	95	16.15	97	16.4	-	-	99	16.8	87	18.3
Fecal Coliform	62	9.9	-	-	-	-	-	-	-	-	50	10
pH	92	10.0	85	9.35	93	10.23	-	-	93	10.2	92	12
BOD	54	5.9	45	4.95	65	7.15	-	-	98	10.8	-	-
Temperature change	92	9.2	92	9.2	93	9.3	-	-	93	9.3	93	11.2
Phosphate	90	9.0	96	9.6	20	2	-	-	55	5.5	99	11.9
Nitrate	96	9.6	97	9.7	97	9.7	-	-	95	9.5	94	11.3
Turbidity	85	6.8	82	6.56	97	7.76	-	-	68	5.4	96	9.6
Total Solids	80	5.6	84	5.88	46	3.22	-	-	80	5.6	-	-
Water Quality Index	79.9		84.9		78.39		-		89		84.3	
Quality of Water	Good		Good		Good		-		Good		Good	

Water Quality Assessment Chart	
90%-100%	Excellent
70%-90%	Good
50%-70%	Medium
25%-50%	Bad
0-25%	Very Bad

As the tables indicate, the water quality at the station monitored has been historically rated good based on water quality indexing and the benthic macroinvertebrates that populate this section of Indian Creek.

4. IDEM Sampling

The Office of Water Management of the Indiana Department of Environmental Management conducted synoptic sampling of the Lower East Fork White River in 1997. Two of seven stations monitored were located on Indian Creek. Station 85-1 was located in Greene County at the State Road 58 Bridge while station 85-2 was located in Martin County at the State Road 450. Both locations were monitored six times in 1997. Various field parameters were collected and measured and extensive general chemistry, nutrient, and metal analyses were performed. Table III-8 presents a portion of that data.

Table III-8
IDEM- Office of Water Management
Monitoring

Station 85-01	Date					
Parameter	03/17/97	04/29/97	06/10/97	07/09/97	09/22/97	12/02/97
Dissolved Oxygen (mg/l)	12.88	10.74	9.96	7.2	7.9	10.81
Temperature (°C)	9.07	17.6	18.2	25.74	19.15	7.09
pH	8.24	8.28	7.72	7.99	7.69	7.98
Turbidity (NTU)	64.5*	6	16.4	4.18	7.7	19.8
Conductivity (µS/cM)	250**	260**	249**	371**	359**	370**
NO_X (mg/L)	0.7**	0.34**	0.59**	0.69**	0.08**	0.14**
Total Phos (mg/L)	<0.05	<0.05	<0.05	<0.05	0.03	0.05
TOC (mg/L)	1.3	1.5	2	1	3.2	3.2
Total Solids (mg/L)	140	160	190	230	250	230
TSS (mg/L)	<4	<4	10	<4	15	<4
TDS (mg/L)	150	140	140	220	220	220
Station 85-02	Date					
Parameter	03/17/97	04/29/97	06/10/97	07/09/97	09/22/97	12/02/97
Dissolved Oxygen (mg/l)	10.95	10.44	8.36	6.51	6.2	9.74
Temperature (°C)	8.04	15.9	17.92	25.19	15.96	6.08
pH	7.57	8.13	7.26	7.68	7.5	7.87
Turbidity (NTU)	212*	16.6	37.1	81.2*	22	18.7
Conductivity (µS/cM)	173**	290**	246**	439**	666	387**
NO_X (mg/L)	0.47**	0.2**	0.82**	0.67**	0.02**	0.05**
Total Phos (mg/L)	0.12	0.04	0.11	<0.05	0.06	0.06
TOC (mg/L)	3	1.6	3.9	2	3.7	3.7
Total Solids (mg/L)	290	180	229	320	520	250
TSS (mg/L)	180	11	34	19	9	<4
TDS (mg/L)	120	150	150	290	470	240

*-high compared to statewide average
**- low compared to statewide average

IV. EXISTING WATERSHED CONDITIONS

1. Wetlands

Wetlands occur in and provide benefits to every county in Indiana. The lack of quantitative information on some aspects of Indiana's wetland resources is a major obstacle to improving wetland conservation efforts.

The most extensive database on wetland resources in Indiana is the National Wetland Inventory (NWI) developed by the U.S. Fish and Wildlife Service. In 1985, the IDNR- Division of Fish and Wildlife entered into a cooperative agreement with The U.S. Fish & Wildlife Service to share the cost of mapping Indiana's wetlands. Indiana's NWI maps were produced primarily from interpretation of high-altitude color infrared aerial photographs taken of Indiana during spring and fall from 1980 through 1987. Map production also included field investigations, review of existing information, quality assurance, draft map production, interagency review of draft maps, and final map production.

NWI maps indicate wetlands by type, using the classification system developed by Cowardin et al. (1979. Classification of wetlands and deepwater habitats of the United States. U.S. Fish and Wildlife Service FWS/OBS-79/31.) The minimum wetlands size on NWI maps is generally one to three acres. Very narrow wetlands in stream and river corridors and wetlands that were cultivated at the time of mapping are generally not depicted, and forested wetlands are poorly discriminated.

The most recent and complete analysis of this database was conducted in 1991 by the IDNR. According to the report, Indiana had approximately 813,000 acres of wetland habitat in the mid-1980s when the data were collected and the various types of wetland habitat are summarized below. The extent of wetland loss or gain since that time is unknown.

Table IV-1
Indiana Wetland Habitats

Wetland Habitats	Acres	% of Total
Scrub-Shrub	42,131	5.2
Forested	504,336	62.0
Wet Meadow	55,071	6.8
Shallow Marsh	67,564	8.3
Deep Marsh	20,730	2.5
Open Water	98,565	8.3
Other	24,633	3.0
Total Wetland habitats	813,032	100.0

The best estimate of the wetlands in Indiana prior to settlement 200 years ago is an assessment based on hydric soils (soils that indicate the presence of wetlands) conducted by the USDA Natural Resources Conservation Service (formerly the Soil Conservation Service). Based on an analysis of this data by the IDNR- Division of Outdoor Recreation in 1989, there were approximately 5.6 million acres of wetlands in Indiana 200 years ago. Combining the information from the NWI and the Division of Outdoor Recreation yields the following summary:

- Total land area 23,226,240 acres
- Estimated wetlands circa 1780s 5,600,00 acres
- Percent of surface area in wetlands circa 1780s 24.1%
- Existing wetlands 813,000 acres
- Percent of surface area in wetlands today 3.5%
- Percent of wetlands lost 85%

Nationwide, Indiana ranks 4th (tied with Missouri) in proportion of wetland acreage lost. The vast majority of the 85% of wetlands lost was due to drainage for agricultural production.

The rich, productive soils available as a result of these drainage activities have contributed significantly to the agriculture industry in Indiana. In 1994, Indiana ranked first in the nation in popcorn production, second in spearmint, fourth in soybeans, fifth in corn for grain, and sixth in overall cash receipts.

The report states that the four counties in which the Indian Creek watershed is located, (Greene, Lawrence, Martin, & Monroe) have wetland acreages less than 3.0% of the surface area. The best estimate of the wetlands in the four counties prior to settlement 200 years ago is also an assessment based on hydric soils found in those particular counties. The assessment is based exclusively on the mapping of hydric in soils in the Soil Surveys of the respective counties and the Hydric Soils of Indiana listing provided by USDA- Natural Resources Conservation Service (NRCS).

Table IV-2
County Hydric Soils

Greene County

Hydric Soil Map Unit	Map Symbol	Soil Texture	Acres	Percent of County Acreage
Ambraw	Ao	sandy clay loam	760	0.2
Armiesburg	Ar	silt loam	630	0.2
Bonnie	Bo	silt loam	8,000	2.3
Booker	Br	clay	3,000	0.9
Booker	Bs	mucky clay	2,400	0.7
Montgomery	Mo	silty clay loam	4,850	1.4
Moskego	Mu	muck	178	0.1
Newark	Ne	loam	3,600	1.0
Nolin	No, Nr	silt loam	2,750	0.8
Patton	Pc	silty clay loam	3,600	1.0
Peoga	Pf	silt loam	6,000	1.7
Rensselaer	Rb	sandy loam	3,500	1.0
Rensselaer	Rd	loam	3,850	1.1
Stendal	St	silt loam	13,200	3.8
Wilhite	Wm	silty clay	1,600	0.5
Zipp	Zp	silty clay	3,300	0.9
Total			**63,218**	**18.1**

Lawrence County

Hydric Soil Map Unit	Map Symbol	Soil Texture	Acres	Percent of County Acreage
Bonnie	Bo	silt loam	958	0.3
Hoosierville	Hs	silt loam	3,842	1.3
Newark	Ne	loam	613	0.2
Nolin	No	silt loam	4,442	1.5
Petrolia	Ph	silty clay loam	727	0.2
Stendal	St	silt loam	2,532	0.9
Total			**13,114**	**4.5**

Martin County

Hydric Soil Map Unit	Map Symbol	Soil Texture	Acres	Percent of County Acreage
Birds	Bk	silt loam	1,160	0.5
Bonnie	Bo	silt loam	1,700	0.8
Newark	Nm	loam	2,700	1.2
Nolin	No	silt loam	2,350	1.1
Wakeland	Wa	silt loam	10,450	4.8
Zipp	Zp	silty clay loam	430	0.2
Total			**18,790**	**8.6**

Monroe County

Hydric Soil Map Unit	Map Symbol	Soil Texture	Acres	Percent of County Acreage
Bonnie	Bo	silt loam	1,345	0.5
Peoga	Po	silt loam	1,755	0.7
Stendal	St	silt loam	3,820	1.4
Wakeland	Wa	silt loam	1,155	0.4
Zipp	Zo, Zp	silty clay loam	880	0.3
Zipp	Zs	variant silt loam	510	0.2
Total			**8,955**	**3.4**

To date, it appears Greene County has lost the greatest percentage of wetland habitat followed by Martin, Lawrence, and Monroe in that order. Wetland acreages of the Indian Creek watershed areas of the four counties are represented based on their landscape position relative to the confluence of Indian Creek with East Fork White River. As the mouth of Indian Creek is located in Martin County, that county has the highest proportion of hydric soils represented followed by Greene, Lawrence, and finally Monroe.

Table IV-3
Indian Creek Watershed
Hydric Soils

County	Watershed Acreage	% of Watershed	Hydric Soil Acreage	% of County within Watershed	% of Total Hydric Soil Acres
Greene	19,800	18.1	110	0.6	3.8
Lawrence	31,200	28.5	100	0.3	3.5
Martin	36,000	32.9	2,650	7.4	91.7
Monroe	22,400	20.5	30	0.1	1.0
Total	**110,000**	**100.0**	**2,890**	**2.6***	**100.0**

*- hydric soils as percentage of watershed

Indian Creek watershed wetlands have been lost or impacted in a variety of ways. The more obvious impacts include agricultural activities, commercial and residential development, road building, water development projects, and vegetation removal. Other activities that may have been contributing factors could include groundwater withdrawal, surface water withdrawal, and water pollution, including sedimentation.

As previously stated, NWI maps indicate wetlands by type including those categories of wetlands that have developed resultant of some activity by man. These wetlands have developed, whether intentionally or unintentionally, in soils that often times involve upland soils as well as hydric soils. Common examples include ponds that are excavated, impoundments created by construction of a dike or dam, and, perhaps the most common, combination structures where soil is incised by excavation and used to construct a dam. Other examples include ditching or fill projects where spoil placement interrupts drainage resulting in wetland habitat.

The NWI maps were relied upon to estimate the acreage of wetlands found in the Indian Creek watershed today. NWI maps are currently available electronically; however, the scale of these drawings are small. To evaluate and quantify wetland acreage within the watershed, drawings were enlarged to measure and compute the total acreages. The following table summarizes the quantification of existing potential wetlands.

Table IV-4
Indian Creek Watershed
Existing Potential Wetlands

County	Watershed Acreage	% of Watershed	NWI Wetland Acreage	% of County within Watershed	% of Total NWI Wetland Acreage
Greene	19,800	18.1	141	0.7	12
Lawrence	31,200	28.5	105	0.3	9
Martin	36,000	32.9	836	2.3	71
Monroe	22,400	20.5	91	0.4	8
Total	110,000	100.0	1,173	1.1*	100

*- NWI Wetland Acreage as percentage of watershed

Applying the method used for the State of Indiana above, the best estimate of the wetlands in the Indian Creek watershed prior to settlement 200 years ago is an assessment based on hydric soils (soils that indicate the presence of wetlands) conducted by the USDA Natural Resources Conservation Service. Based on an analysis of the hydric soils mapped in the soil surveys of the four counties and located in the Indian Creek watershed, there were approximately 2,890 acres of wetlands in the Indian Creek watershed 200 years ago. Combining the information from the NWI and the assessment of hydric soils mapped in the soil surveys yields the following summary:

- Total land area 110,000 acres
- Estimated wetlands circa 1780s 2,890 acres
- Percent of surface area in wetlands circa 1780s 2.6%
- Existing wetlands 1,173 acres
- Percent of surface area in wetlands today 1.1%
- Percent of wetlands lost 59%

This assessment suggests that wetland loss within the Indian Creek watershed is somewhat less than the loss experienced statewide during the same time period.

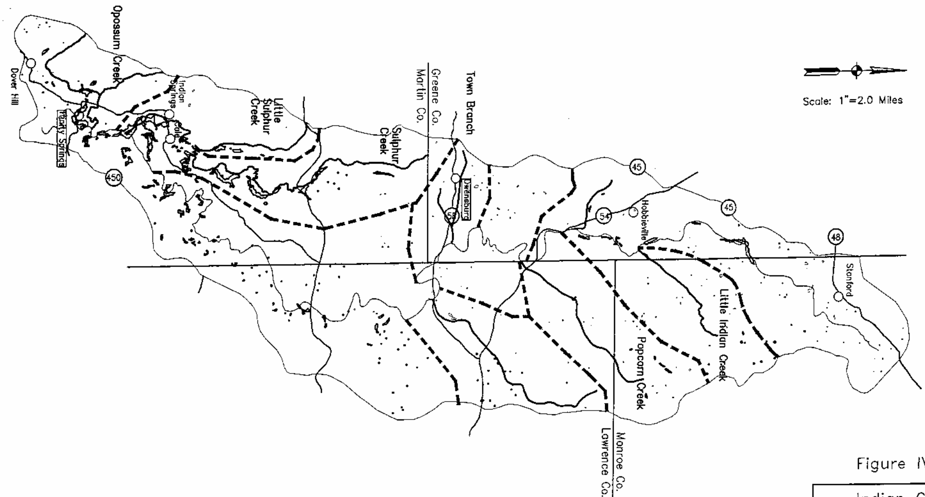


Figure IV-1

Indian Creek Watershed Project

Wetlands Map

Legend					
Wetlands	Greene County	Lawrence County	Martin County	Monroe County	Total Acreage
Natural Wetlands	103 Acres	82 Acres	815 Acres	37 Acres	1,037 Acres
Constructed Wetlands	37 Acres	23 Acres	21 Acres	54 Acres	136 Acres
Total Acreage	141 Acres	105 Acres	836 Acres	91 Acres	1,173 Acres

Subwatershed Boundary

DONAN ENGINEERING CO., INC.
4342 North US 231
Jasper, IN 47546
(812) 482-5611

C:\EJK\Jare\INDIANCR\drawings\Indian-Creek-Wetland.dwg Thu Jan 18 09:59:30 2001 CDH

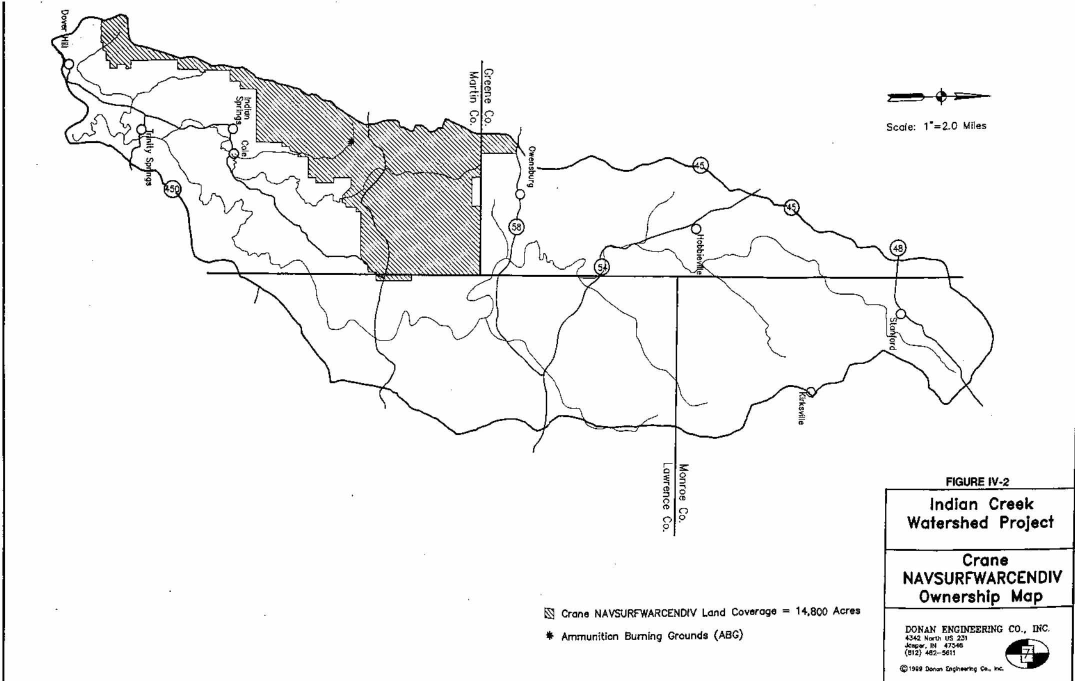


FIGURE IV-2

Indian Creek Watershed Project

Crane NAVSURFWARCENDIV Ownership Map

2. Crane

The Naval Surface Warfare Center, Crane Division (Crane) is located within the northern half of Martin County and portions of Greene, Daviess, and Lawrence Counties. The facility encompasses approximately 96 square miles (62,463 acres). The majority of the facility is wooded.

Crane has over a fifty-year history of operations. In 1940, Congress authorized construction of a naval Ammunition Depot in southern Indiana. In late 1941, the Burns City Naval Ammunition Depot was commissioned. In 1943, NAD Burns City was renamed NAD Crane, and the town of Crane was built to house the rapidly growing number of civil service employees at the facility. NAD Crane's overall mission was to load, prepare, renovate, receive, store, and issue ammunition to the U.S. Naval fleet.

During World War II, NAD Crane's mission expanded to include pyrotechnics production, mine filling rocket assembly, field storage, torpedo storage, and ordnance spare parts and mobile equipment storage. During the 1950s, several new departments were created, the Ammunition Loading and Production Engineering Center (ALPEC) was transferred to Crane, and the Central Ammunition Supply Control Office (CASCO) was established. NAD Crane supplied ammunition to the fleet during the Korean and Vietnam Conflicts. During the Southeast Asia crisis, the number of full-time employees at NAD Crane grew to 6,800.

In 1976, NAD Crane was designated Naval Weapons Support Center Crane (NWSCC). Its new mission was to provide support for ship and aircraft equipment, shipboard weapons systems and assigned ordnance items, and to perform additional functions as directed.

In 1997, the Crane Army Ammunition Activity (CAAA) was created, and the Army assumed ordnance production, storage, and related responsibilities as a tenant organization. Other functions remained Navy, and currently Navy retains ownership of all real estate and facilities at Crane. Responsibility for overall facility safety, security, and environmental protection remains with the Naval Commanding Officer. Most recently in 1992, Crane was designated NAVSURFWARCENDIV. Presently approximately 4,000 people are employed at the facility.

Crane contains a substantial amount of undeveloped land that has experienced minimal effects by man. Approximately 56,320 acres of the total 62,463 acres are managed under the natural resources management program and total acreage is broken down as follows:

Table IV-5
Crane Land Use

Land Use	Acres
Buildings and paved surfaces	6,143
Improved areas (lawns, golf course, ball park)	209
Semi-improved areas (right-of-ways)	4,802
Unimproved areas (forests, lakes, ponds)	51,309
Total	**62,463**

The entire 56,111 acres is available for hunting and other land recreational uses subject to security and other considerations at Crane. Included are approximately 900 acres of lakes, streams, and ponds.

The major source for water quality problems in this region is runoff from both agricultural and undeveloped lands. Because of the steep slopes throughout much of Crane, there is a need to keep areas near water bodies well vegetated to reduce sedimentation and pollution from chemicals (fertilizer, pesticides, etc.) that may be used in the area. The military work at Crane is confined to central locations outside the Indian Creek watershed and the rest of the area is well vegetated. As such, the greatest threat for pollution comes during flooding when areas are exposed to high flow rates of runoff.

In addition to the nonpoint source pollution discussed above, Crane has identified 30 Solid Waste Management Units (SWMU) which are areas that, for an assortment of reasons, have the potential to impact surface runoff beyond the impact expected from unimproved or semi-improved areas. Only one such SWMU was identified in the Indian Creek watershed that appeared to have the potential to impact surface runoff. The Ammunition Burning Ground (ABG) is located near the northeast corner of the facility near Little Sulphur Creek.

The Indian Creek watershed area of Crane is approximately 14,800 acres located on the east side. Essentially all of the buildings and the improved areas of the facility fall west of the Indian Creek watershed. The existence of and adherence to a management plan or the natural resources of the facility suggest that the Crane component of the Indian Creek watershed could be regarded as background pollution levels against which other land uses are judged.

The ABG covers approximately 20 acres of the facility. This SWMU is located near the east center boundary in a remote area within the valley of Little Sulphur Creek. This creek is intermittent in that its flow varies considerably with the seasons. Surface flow ceases in the dry months of the year as the water is captured by vertical infiltration into the underlying sandstone and limestone aquifer beneath ABG.

Ordnance and ordnance-contaminated materials from the facilities production areas have been taken to ABG for disposal by burning since the 1940s. This burning ground has been used extensively for destroying unwanted materials contaminated with explosives, bare explosives, rocket motors, candles, flares, solvents, detonators, and fuse materials. A variety of separate burning areas are located within the site proper. The area is also used for flashing the residues from bombs and projectiles after they have been subjected to melt-out or drill-out operations. Powder flashing and bomb burnout were also conducted at an adjacent area called Jeep Trail.

The largest quantities of materials were destroyed at this SWMU from 1956 to 1960, when 15,000 lbs per day of smokeless powder was flashed. In the same period approximately 46,000 lbs per day of high explosives were burned.

In 1997, a human health and environmental risk assessment was prepared and presented as being consistent with the latest U.S. EPA risk assessment guidance-"Risk Assessment Guidance for Superfund. Volume I. Human Health Evaluation Manual (Part A) and Volume II. Environmental Evaluation Manual" (USEPA, 1989a,b). This report states that:

"Population studies within and outside of the impacted area of the ABG do not indicate on the basis of abundance and diversity an adverse effect to the indicator species investigated resulting from operation of the ABG. As a result of the combination of low trace levels of metals and organics detected in the media and tissues associated with the Ammunition Burning Ground and the population studies conducted at the site, the effects of the current activities at this SWMU are not considered to be adversely impacting the ecological population at this site. Implementing a surface water erosion control program to prevent erosion and surface runoff from reaching the surface water preventing sedimentation would further reduce any potential aquatic risk."

3. Demographics/ Development Trends

In the period from 1990 through 1997, the State of Indiana grew from 5,544,156 residents to 5,864,108 - an increase of about 5.8%. In the same time period, the four counties which have part of their area in the Indian Creek watershed experienced growth of 6.8%. From 1990 to 1997, Greene County and Lawrence County increased 8.8% and 6.3% respectively while Martin County's population grew 1.4%. Monroe County showed an increase during this period of 7%. Over half of the population of Monroe County resides in the City of Bloomington however, which is outside of the Indian Creek watershed.

Projections into the future predict that from the 1997 estimate to the year 2020, the four counties will have population growth of some 21,000 residents which is an increase of >10%. This growth is essentially the same rate of increase projected for the State of Indiana. Since only portions of the four counties are within the watershed of Indian Creek, it does not necessarily follow that the population of Indian Creek watershed will increase at the rates predicted for the entire counties. The reader is cautioned therefore, that this data should only be relied upon to predict trends in development.

Table IV-6
Population Projections
of Counties in
Indian Creek Watershed

County	Census	Estimate	Projections				
	1990	1997	2000	2005	2010	2015	2020
Indiana	5,544,156	5,864,108	6,044,528	6,215,296	6,318,404	6,404,070	6,481,489
Greene	30,410	33,074	34,134	35,138	35,743	36,247	36,702
Lawrence	42,836	45,539	46,927	48,241	49,035	49,694	50,289
Martin	10,369	10,510	10,505	10,500	10,497	10,495	10,493
Monroe	108,978	116,653	120,429	124,003	126,161	127,954	129,574
4 Counties	192,593	205,773	211,995	217,882	221,436	224,390	227,058

Historical information was compiled at the township level for Indian Creek watershed. Table IV-7 shows that the Greene County component (Center & Jackson Townships) of the watershed had the greatest rate of growth for the period from 1990 to 1996. This limited information is not sufficient for predicting future township or watershed population growth. Rather, this information is presented as a basis for establishing trends and patterns of development for the areas of the watershed.

Table IV-7
Population Changes
for Townships in
Indian Creek Watershed

County/Township	Population			Percent Change	
	1960	1990	1996	1960-90	1990-96
Greene County	26,327	30,410	32,942	15.51	8.33
Center	1,137	2,439	2,727	114.51	11.81
Jackson	1,059	1,499	1,676	41.55	11.81
Lawrence County	36,564	42,836	45,361	17.15	5.89
Indian Creek	1,467	2,528	2,676	72.32	5.85
Perry	1,046	1,726	1,827	65.01	5.85
Spice Valley	1,910	1,988	2,105	4.08	5.89
Martin County	10,608	10,369	10,581	-2.25	2.04
Center	1,499	1,820	1,890	21.41	3.85
Mitcheltree	788	706	726	-10.41	2.83
Perry	5,347	5,126	5,143	-4.13	0.33
Monroe County	59,225	108,978	116,176	84.01	6.61
Indian Creek	770	1,429	1,493	85.58	4.48
Van Buren	2,209	10,470	11,036	78.95	4.45

4. Recreational Stream Use

Public access lakes generally have a mechanism for monitoring fishing and other recreational uses. This information can be estimated based on gate counts, usage fees, surveys, and various other mechanisms. Unfortunately these mechanisms are generally not applicable to monitoring the recreational usage of streams.

5. Land Use

The term "land use" often is associated with zoning, which denotes a method used by regional planners to divide an area into districts in which certain activities are permitted. The land use description or categorization identifies the principal activity-taking place in such districts or aerial units. Although zoning or divisions of areas according to the primary activity originally had little relationship to water quality, it has been realized that water quality loadings from nonpoint sources can, to a certain degree, be correlated with land use and intensity of land use activities. An example of such a correlation is seen in Figures IV-8 & IV-9.

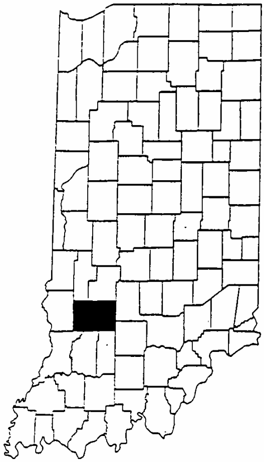
The problem of land use and its effect on water quality is generally associated with urban and agricultural developments. Spreading urban and uncontrolled streamside developments can result in deterioration of water quality. Impervious streets, roofs, and other areas increases runoff coefficients and even small rains are capable of washing accumulated pollutants into surface waters. Failed on-site septic systems associated with unsewered residential development are an additional source of elevated pollution loading to a stream.

In rural areas, animal barnyards and feedlots as well as conventional tillage on highly erodible lands can produce high sediment and nutrient loading, especially if over fertilization is prevalent. The pollution loading potential of land use activities then, can be classified into three categories:

1. Land not in need of control, including unmanaged forestland and idle permanently vegetated open land.
2. Land sometimes needing control measures such as pasture, hayland, and in particular, cropland.
3. Land usually requiring control measures; typical examples are some urban areas with residential, commercial, and industrial areas, mining operations, construction sites, and animal feedlots. These land use activities generally are considered to be the most threatening to water quality.

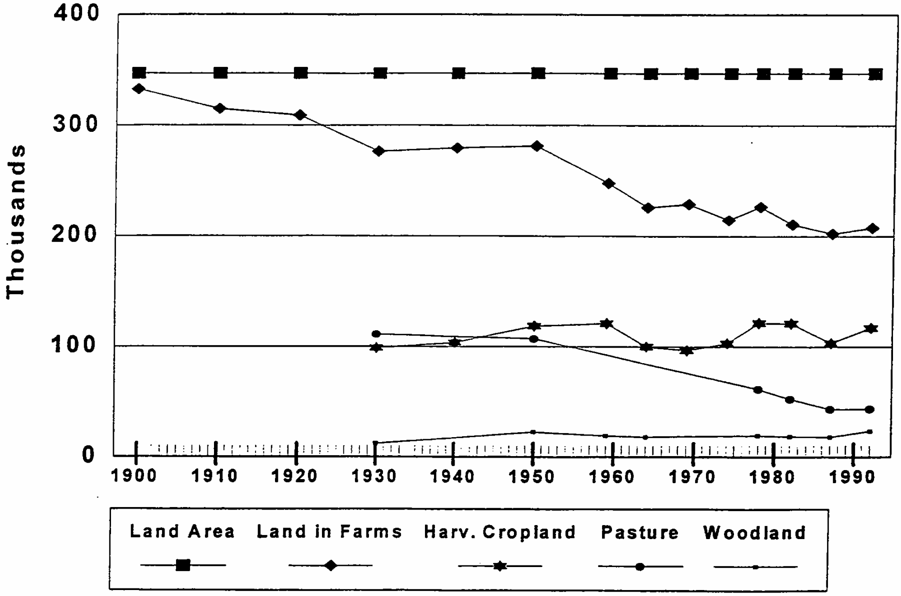
Indian Creek watershed as a whole would most likely compare with the "mostly forest" category presented in Figures IV-8 & IV-9. It appears that land use and topography are more diverse within the individual counties involved than a comparison of the portions of the counties that make up the Indian Creek watershed. Figures IV-10, IV-11, & IV-12 show proportions of land uses on a countywide basis for the counties in which this information was available.

INDIANA FARM LAND USE HISTORY
Greene County, Indiana



Total Land Area 1992 - 346,967 Acres

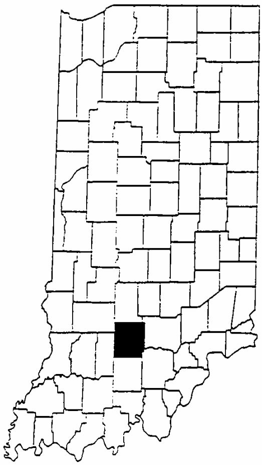
Year	Land in Farms	Harvested Cropland	Land Pastured	Woodland Not Pastured
		------- Acres -------		
1900	332,759	n/a	n/a	n/a
1910	315,073	n/a	n/a	n/a
1920	309,198	n/a	n/a	n/a
1930	276,353	98,781	111,371	12,175
1940	279,489	103,795	n/a	n/a
1950	281,305	118,859	107,206	22,691
1959	247,729	121,210	n/a	19,450
1964	226,003	100,172	n/a	18,428
1969	229,054	96,804	n/a	n/a
1974	214,619	103,279	n/a	n/a
1978	226,609	121,777	61,771	19,588
1982	210,812	121,314	52,853	18,793
1987	202,544	103,559	43,778	18,310
1992	207,766	117,268	43,987	23,773



Source: U.S. Census of Agriculture
Assembled January 1997
Purdue University Cooperation Extension Service

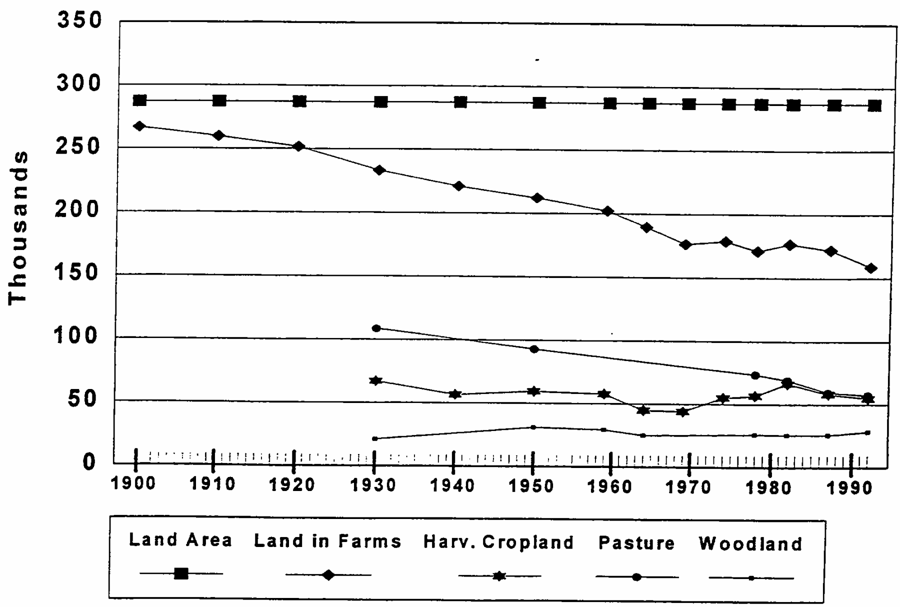
FIGURE IV-3

INDIANA FARM LAND USE HISTORY
Lawrence County, Indiana



Total Land Area 1992 - 287,271 Acres

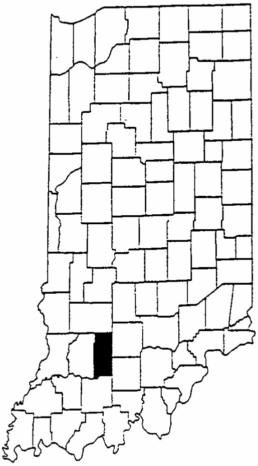
Year	Land in Farms	Harvested Cropland	Land Pastured	Woodland Not Pastured
	------- Acres -------			
1900	266,945	n/a	n/a	n/a
1910	259,799	n/a	n/a	n/a
1920	251,658	n/a	n/a	n/a
1930	233,309	67,035	108,641	21,410
1940	221,139	56,487	n/a	n/a
1950	212,153	59,449	92,980	31,121
1959	202,187	57,691	n/a	29,423
1964	189,656	45,088	n/a	25,391
1969	176,450	44,236	n/a	n/a
1974	178,613	54,963	n/a	n/a
1978	171,048	56,517	73,695	26,072
1982	176,673	66,487	69,152	25,866
1987	172,226	58,223	59,426	25,968
1992	158,788	54,883	57,451	28,609



Source: U.S. Census of Agriculture
Assembled January 1997
Purdue University Cooperation Extension Service

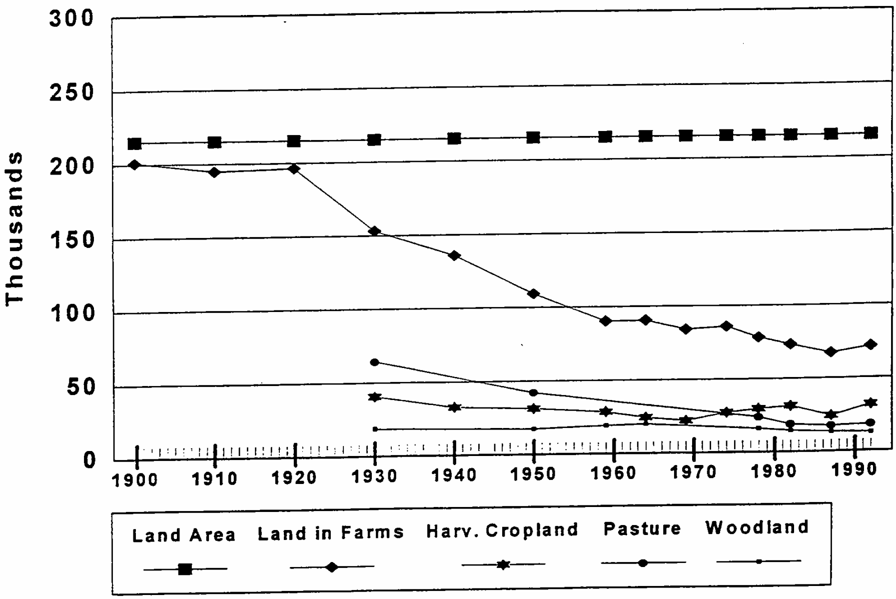
FIGURE IV-4

INDIANA FARM LAND USE HISTORY
Martin County, Indiana

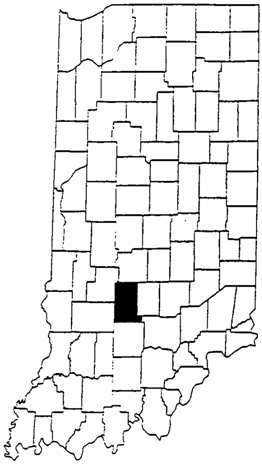


Total Land Area 1992 - 215,141 Acres

Year	Land in Farms	Harvested Cropland	Land Pastured	Woodland Not Pastured
	------- Acres -------			
1900	201,006	n/a	n/a	n/a
1910	194,877	n/a	n/a	n/a
1920	196,490	n/a	n/a	n/a
1930	153,155	40,502	64,478	18,689
1940	135,980	32,645	n/a	n/a
1950	109,233	31,103	42,034	17,381
1959	90,328	28,522	n/a	19,191
1964	90,663	24,485	n/a	20,018
1969	84,221	21,981	n/a	n/a
1974	85,943	27,213	n/a	n/a
1978	78,363	29,606	24,049	16,187
1982	73,369	31,306	18,809	14,633
1987	67,373	24,308	17,556	13,470
1992	71,596	31,723	18,369	12,847

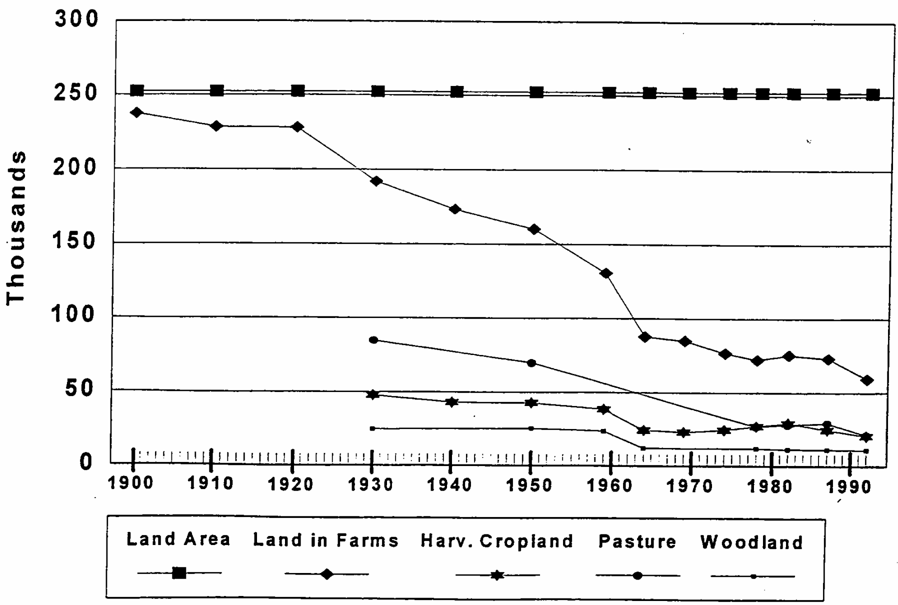


INDIANA FARM LAND USE HISTORY
Monroe County, Indiana



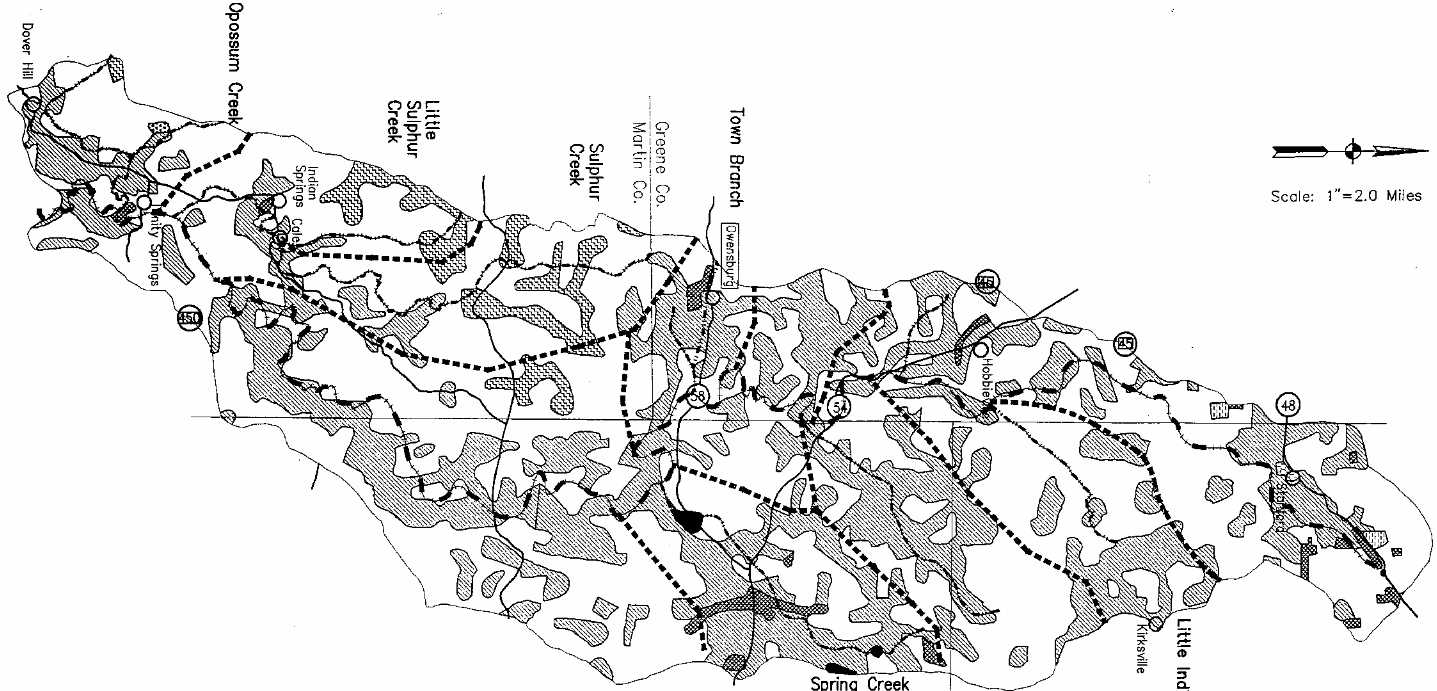
Total Land Area 1992 - 252,400 Acres

Year	Land in Farms	Harvested Cropland	Land Pastured	Woodland Not Pastured
		------- Acres	-------	
1900	237,552	n/a	n/a	n/a
1910	228,541	n/a	n/a	n/a
1920	228,170	n/a	n/a	n/a
1930	191,985	47,842	84,748	24,665
1940	173,293	42,982	n/a	n/a
1950	160,151	42,803	69,900	25,316
1959	130,841	38,489	n/a	23,768
1964	87,773	24,375	n/a	12,139
1969	84,991	23,227	n/a	n/a
1974	76,681	24,592	n/a	n/a
1978	72,157	27,135	26,869	11,865
1982	75,330	29,212	28,320	11,369
1987	73,054	24,708	29,238	11,249
1992	59,282	20,576	21,170	10,958



Source: U.S. Census of Agriculture
Assembled January 1997
Purdue University Cooperation Extension Service

FIGURE IV-6



Land Uses	Opossum Creek	Sulphur Creek	Spring Creek	Popcorn Creek	Little Indian Cr.	Total Acreage
Residential	———	40 Acres	580 Acres	10 Acres	———	1,370 Acres
Commercial/Services	70 Acres	2,650 Acres	———	———	———	3,340 Acres
Industrial	———	———	———	———	———	160 Acres
Crop/Pasture	1,610 Acres	1,890 Acres	4,700 Acres	3,580 Acres	3,880 Acres	38,540 Acres
Deciduous Forest	3,670 Acres	14,420 Acres	2,430 Acres	6,110 Acres	2,920 Acres	66,270 Acres
Evergreen Forest	50 Acres	———	———	———	———	50 Acres
Mine/Quarry/Gravel	———	———	190 Acres	———	———	200 Acres
Mixed Urban	———	———	———	———	———	70 Acres
Total Acreage	5,400 Acres	19,000 Acres	7,900 Acres	9,700 Acres	6,800 Acres	110,000 Acres

Legend

Subwatershed Boundary

Figure IV–7

Indian Creek Watershed Project
Project No. 279

Land Use Map

DONAN ENGINEERING CO., INC.
4342 North US 231
Jasper, IN 47546
(812) 482-5611

:\EJK\lare\INDIANCR\drawings\landuse-subwatershed.dwg Wed Dec 27 15:20:55 2000 CDH

Figure IV-8

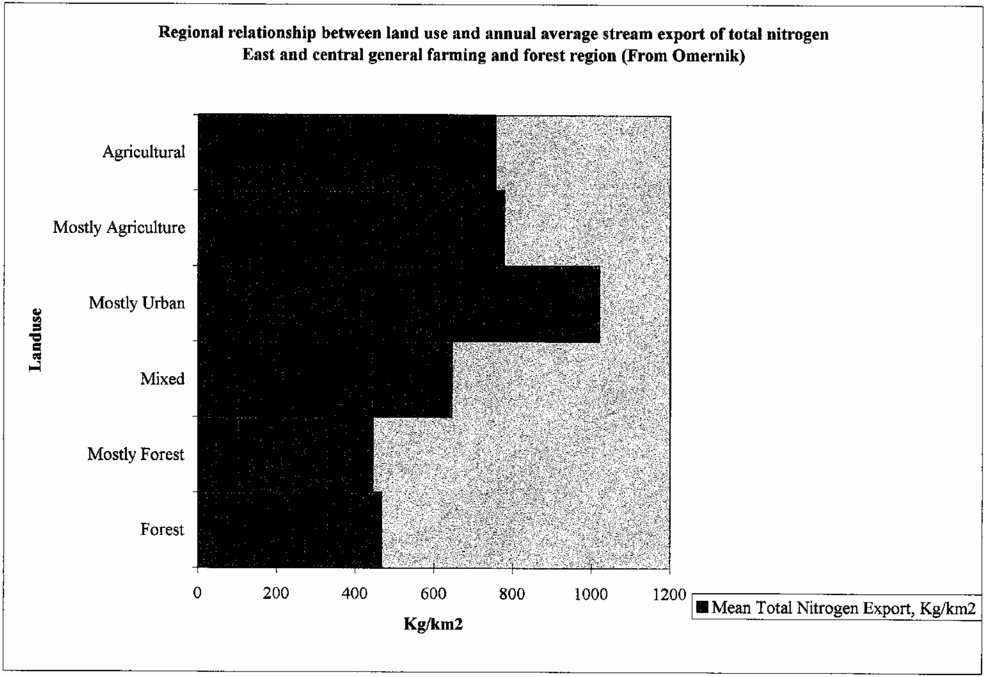
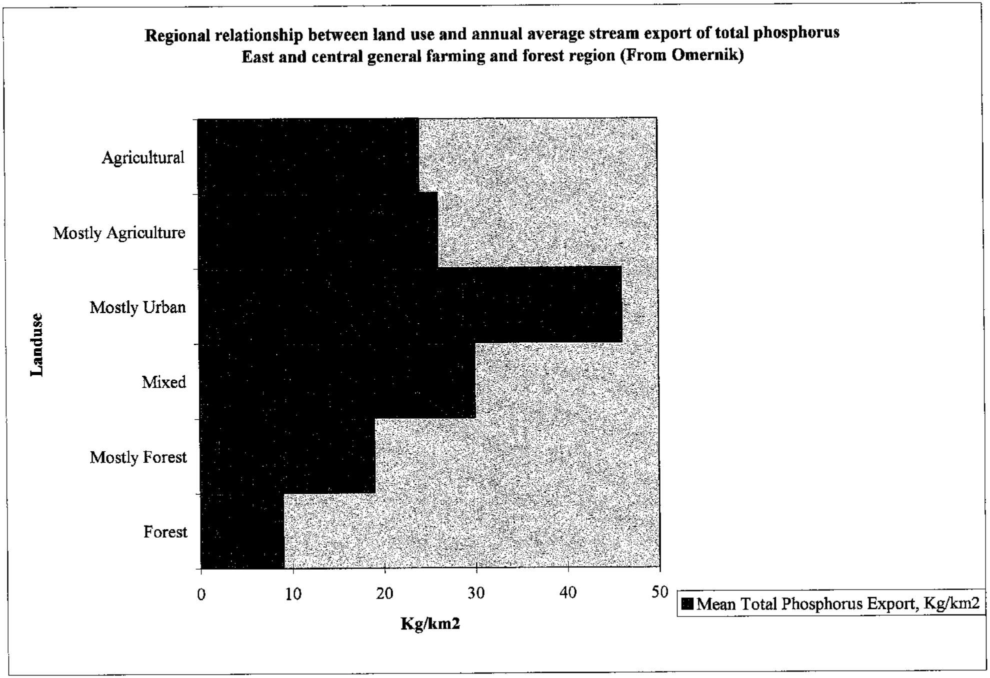

Regional relationship between land use and annual average stream export of total nitrogen
East and central general farming and forest region (From Omernik)
Landuse
Agricultural
Mostly Agriculture
Mostly Urban
Mixed
Mostly Forest
Forest
0
200
400
600
800
1000
1200
Kg/km2
Mean Total Nitrogen Export, Kg/km2

Figure IV-9


Regional relationship between land use and annual average stream export of total phosphorus
East and central general farming and forest region (From Omernik)
Landuse
Agricultural
Mostly Agriculture
Mostly Urban
Mixed
Mostly Forest
Forest
0
10
20
30
40
50
Kg/km2
Mean Total Phosphorus Export, Kg/km2

The size of the watershed prohibited the mapping of land uses on a field-by-field basis. Instead, a map was generated electronically, which identifies general categories of land use on a broader basis. Figure IV-7, the land use map for the Indian Creek watershed was generated from EPA's Spatial Data Library System and National Shape File Repository. The table in Figure IV-7 shows the land use of the watershed in acres and the acreages as a percentage of the total are represented in Figure IV-13. The table in Figure IV-7 also summarizes the land use categories by subwatershed. Figures IV-14 through IV-18 depict the proportions of landuse categories in the identified sub-watersheds.

Studies of non-point source pollution tend to focus on identifying and quantifying non-point source loads associated with various land uses. However, landform characteristics can have a greater impact on the extent of non-point sources pollution than the land use. As an example, the watershed of Pigeon Creek in Gibson, Warrick, and Vanderburg Counties has extensive areas of land used exclusively for row crop production with conventional tillage. Those areas are predominantly prime farmland areas having 0 to 2 percent slopes. While the Indian Creek watershed does have significant prime farmland in floodplain areas, the majority of the watershed would not support an agricultural enterprise of continuous corn production- both from an economic and ecological perspective. There is not a predetermined combination of land uses that are appropriate for a watershed. The concerns of no point source pollution have to do more with selecting a land use appropriate for the landform available.

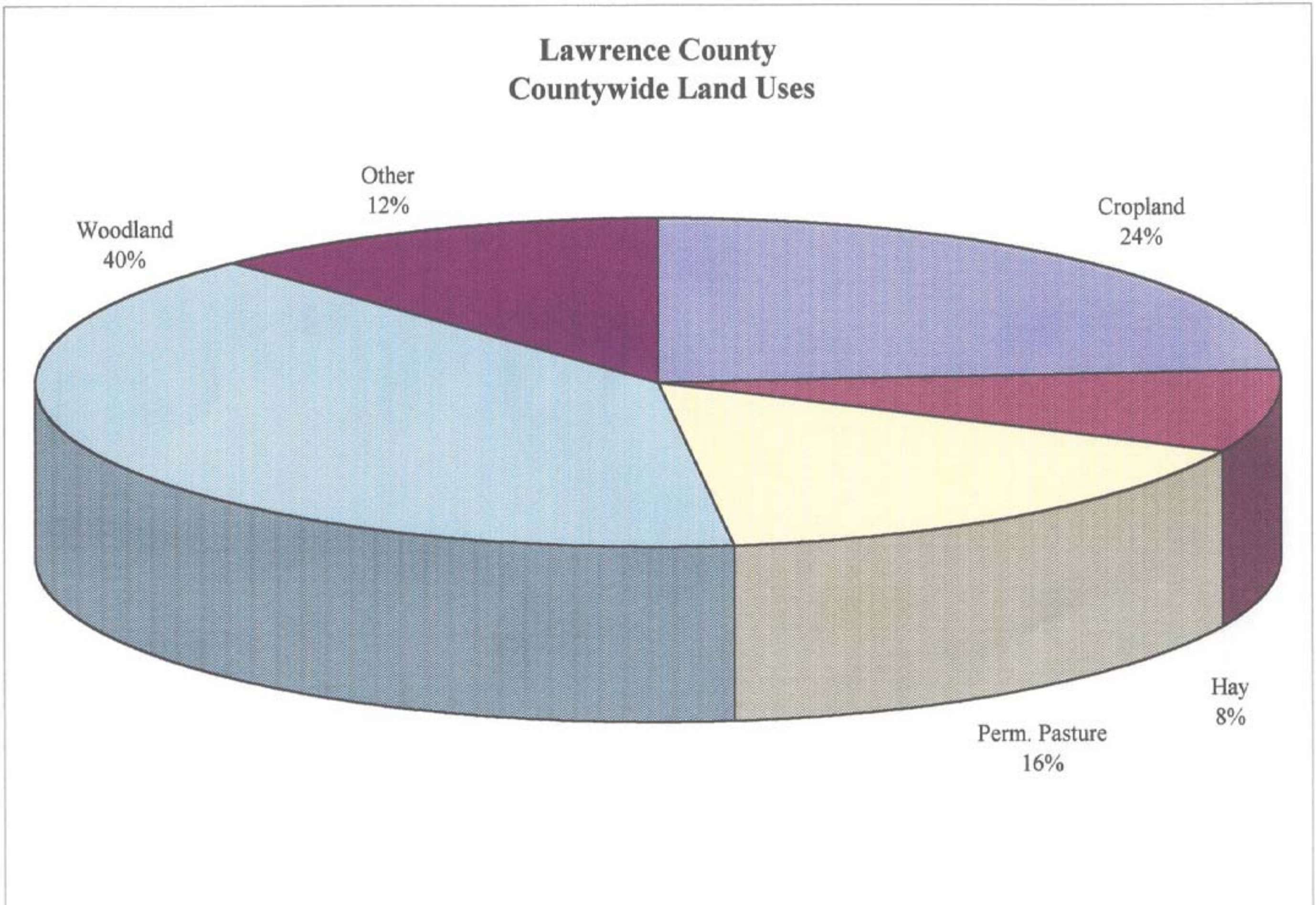
A. Land Use Categories

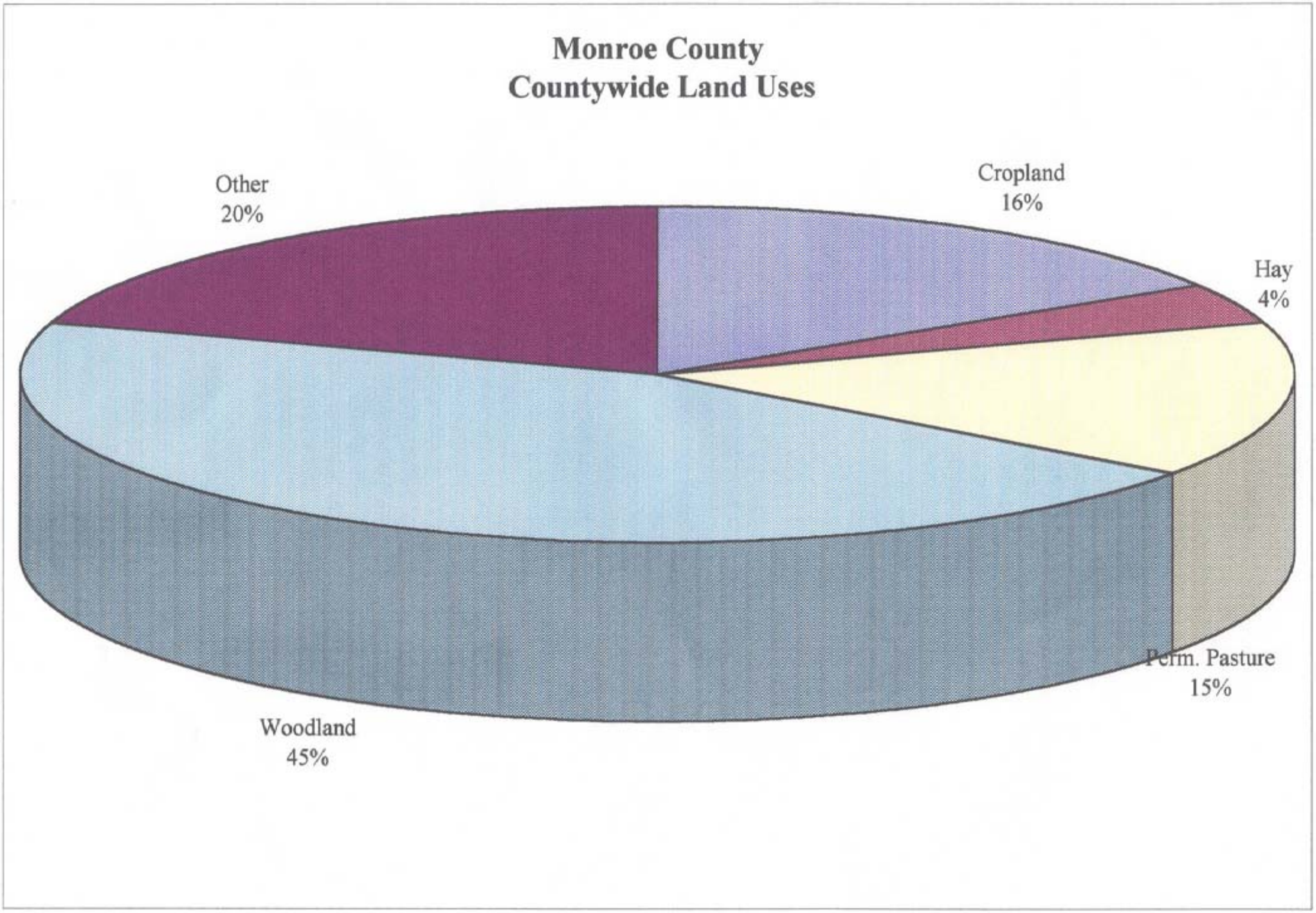
The term land use describes the prevailing activity taking place in an essentially uniform demographic area. Lands classified into a single land use category may be quite diversified with regard to topography, soil types, slope, and other important factors. Therefore, wide variability in potential pollutant loading within a single land use category should be expected.

Land use categories for the Indian Creek watershed are divided into generally rural and urban types. Urban types include residential, commercial, industrial, and mixtures of these urban uses. The rural connotation refers to forest, mine areas, and crop/pasture land. Detailed land use inventories often recognize as many as 50 categories and sub-categories. Due to the wide variations in pollutional loadings within each land use category, it is not possible to estimate pollution impact for each detailed land use category. For watershed pollution studies, land uses are grouped together into more general categories, which bear a certain distinct relationship to generation of pollutants.

Land use is a simple term describing the prevailing activity occurring in an area and, as such, it bears little relationship to pollution generated from that area. Although the activity per se may produce some pollution directly, many other factors must be considered in predicting pollution-loading rates. If one intends to trace the origin and causes of the pollution, the land use activity description loses its meaning, and more meaningful factors such as dust and dirt accumulation rates on impervious areas, soil type and slope, vegetative cover, atmospheric deposition, etc. are more closely related to the pollutant loading. A partial list of factors that

Figure IV-10


Lawrence County
Countywide Land Uses
Other
12%
Cropland
24%
Woodland
40%
Hay
8%
Perm. Pasture
16%


Monroe County
Countywide Land Uses
Other
20%
Cropland
16%
Hay
4%
Perm. Pasture
15%
Woodland
45%

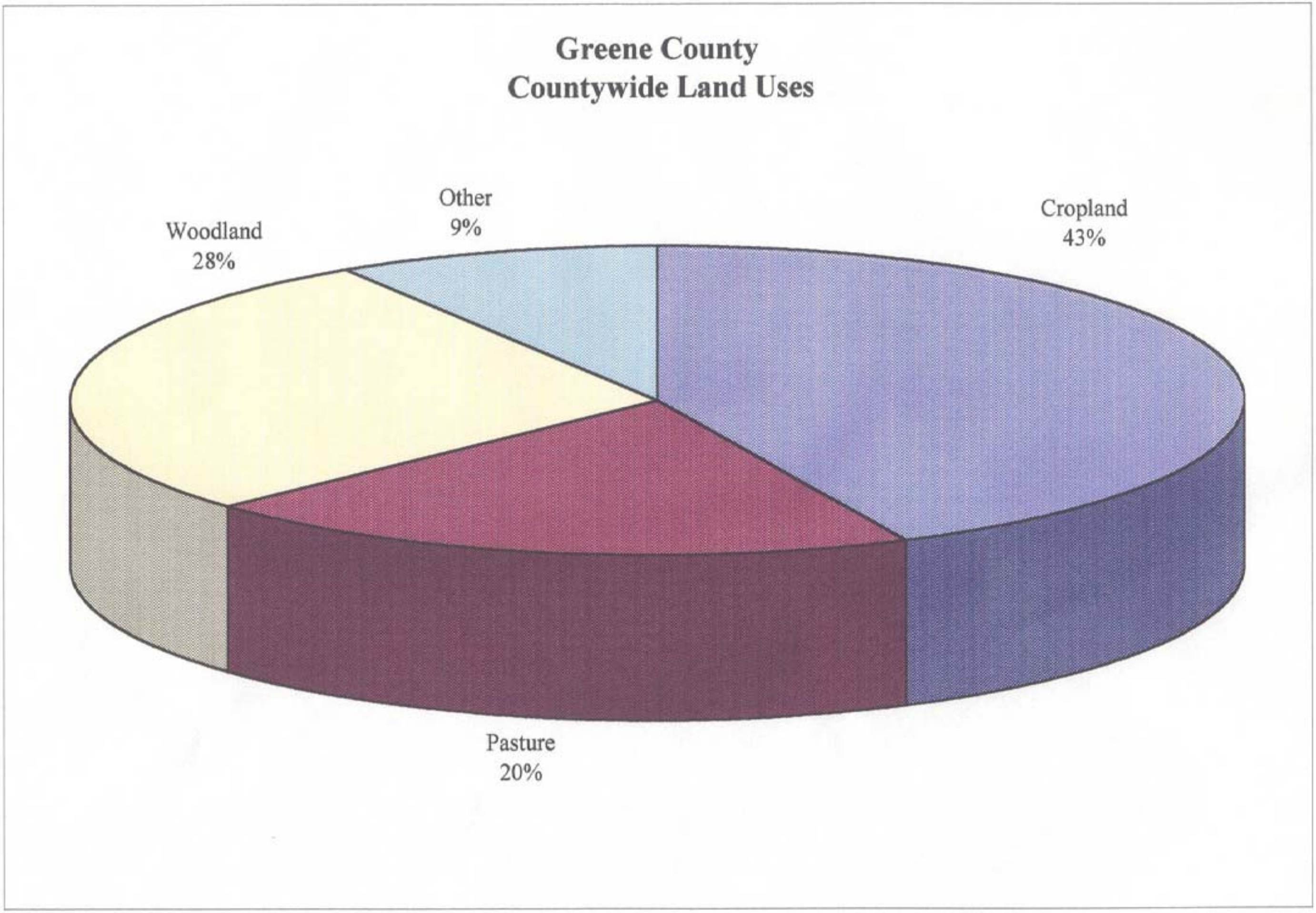
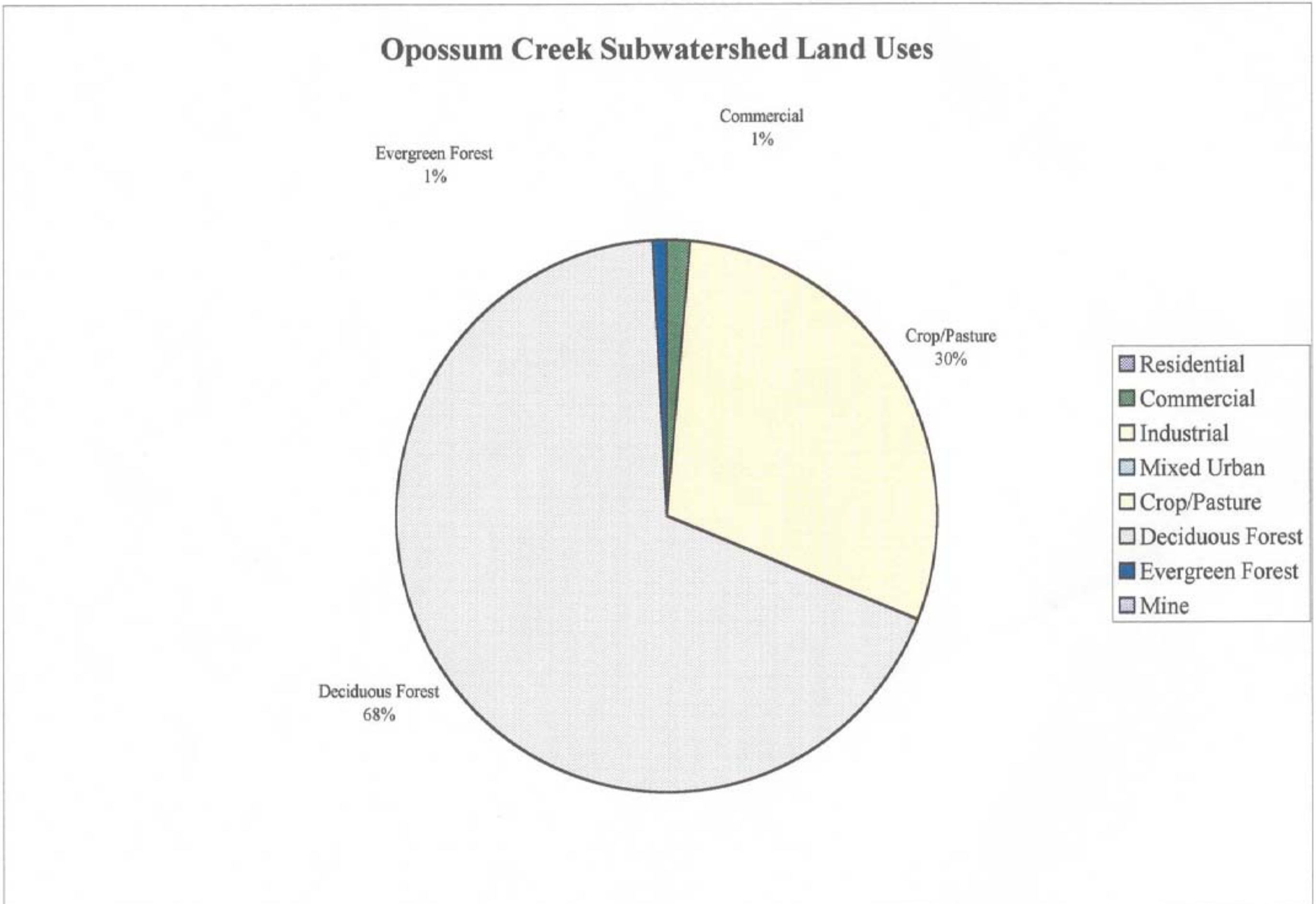

Greene County
Countywide Land Uses
Other
9%
Woodland
28%
Cropland
43%
Pasture
20%

Figure IV-14



Opossum Creek Subwatershed Land Uses
Commercial
1%
Evergreen Forest
1%
Crop/Pasture
30%
Deciduous Forest
68%
Residential
Commercial
Industrial
Mixed Urban
Crop/Pasture
Deciduous Forest
Evergreen Forest
Mine

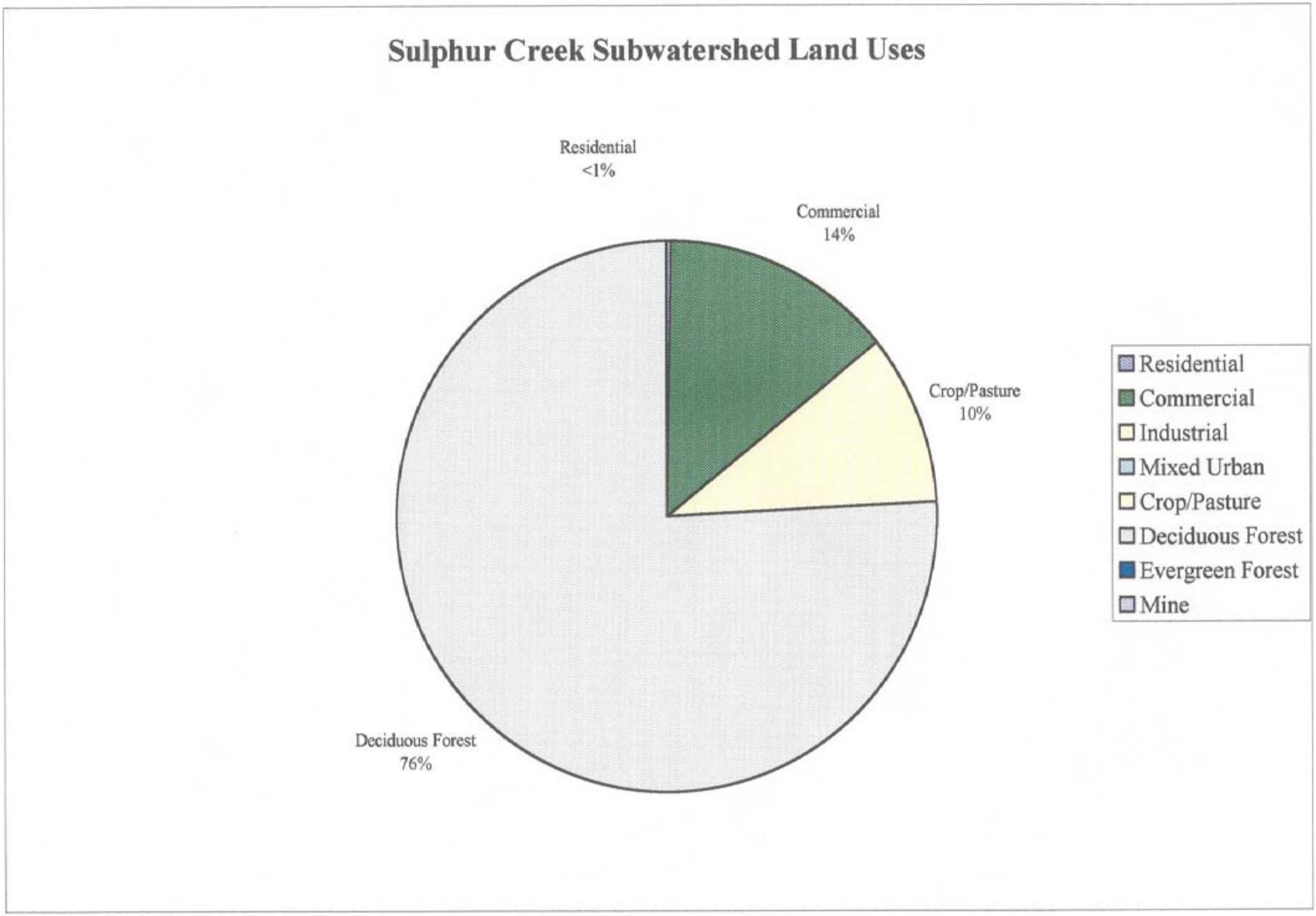
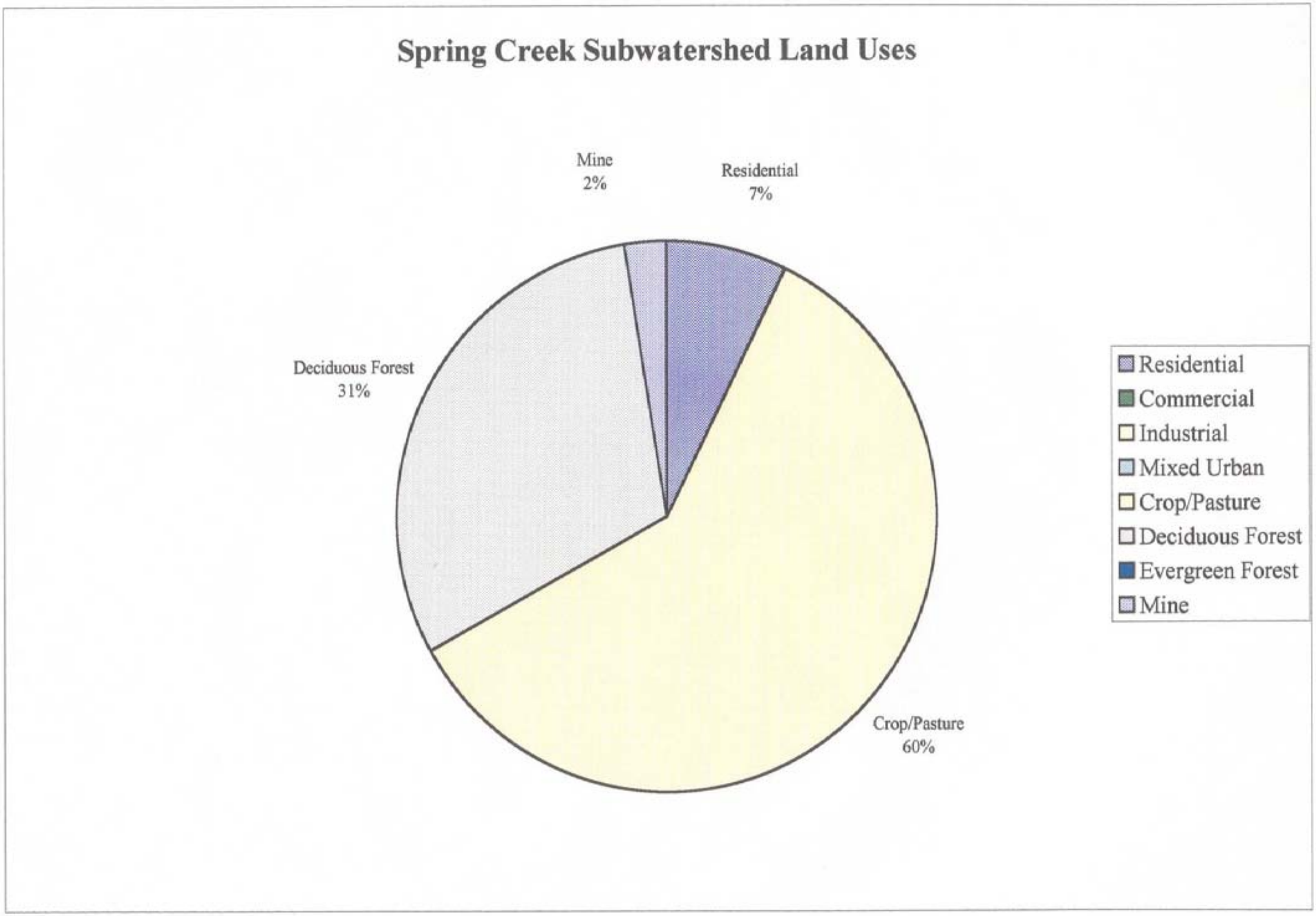

Sulphur Creek Subwatershed Land Uses
Residential
<1%
Commercial
14%
Crop/Pasture
10%
Deciduous Forest
76%
Residential
Commercial
Industrial
Mixed Urban
Crop/Pasture
Deciduous Forest
Evergreen Forest
Mine

Figure IV-16



Spring Creek Subwatershed Land Uses
Mine
2%
Residential
7%
Deciduous Forest
31%
Crop/Pasture
60%
Residential
Commercial
Industrial
Mixed Urban
Crop/Pasture
Deciduous Forest
Evergreen Forest
Mine

Figure IV-17

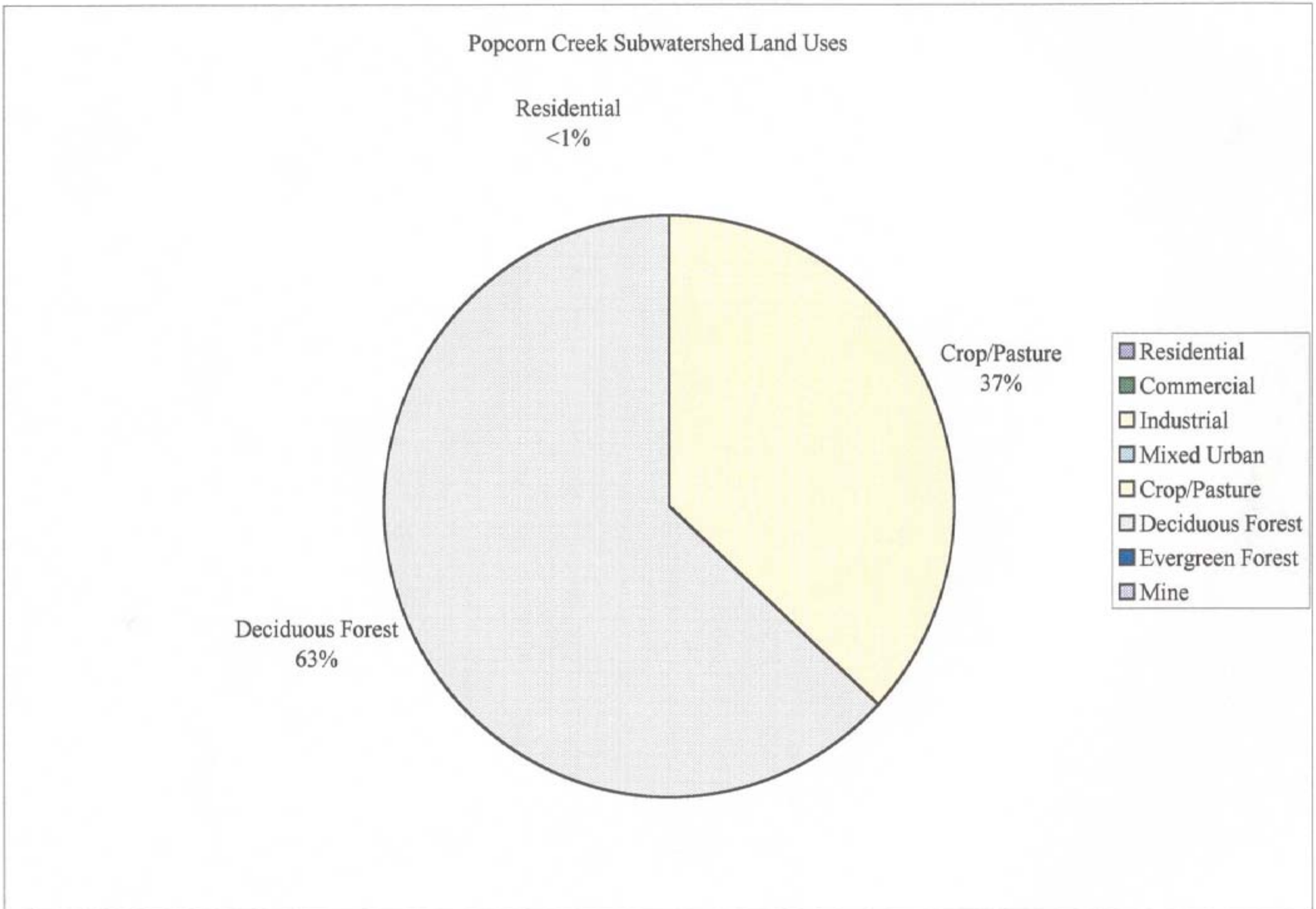

Popcorn Creek Subwatershed Land Uses
Residential
<1%
Crop/Pasture
37%
Deciduous Forest
63%
Residential
Commercial
Industrial
Mixed Urban
Crop/Pasture
Deciduous Forest
Evergreen Forest
Mine

Figure IV-18

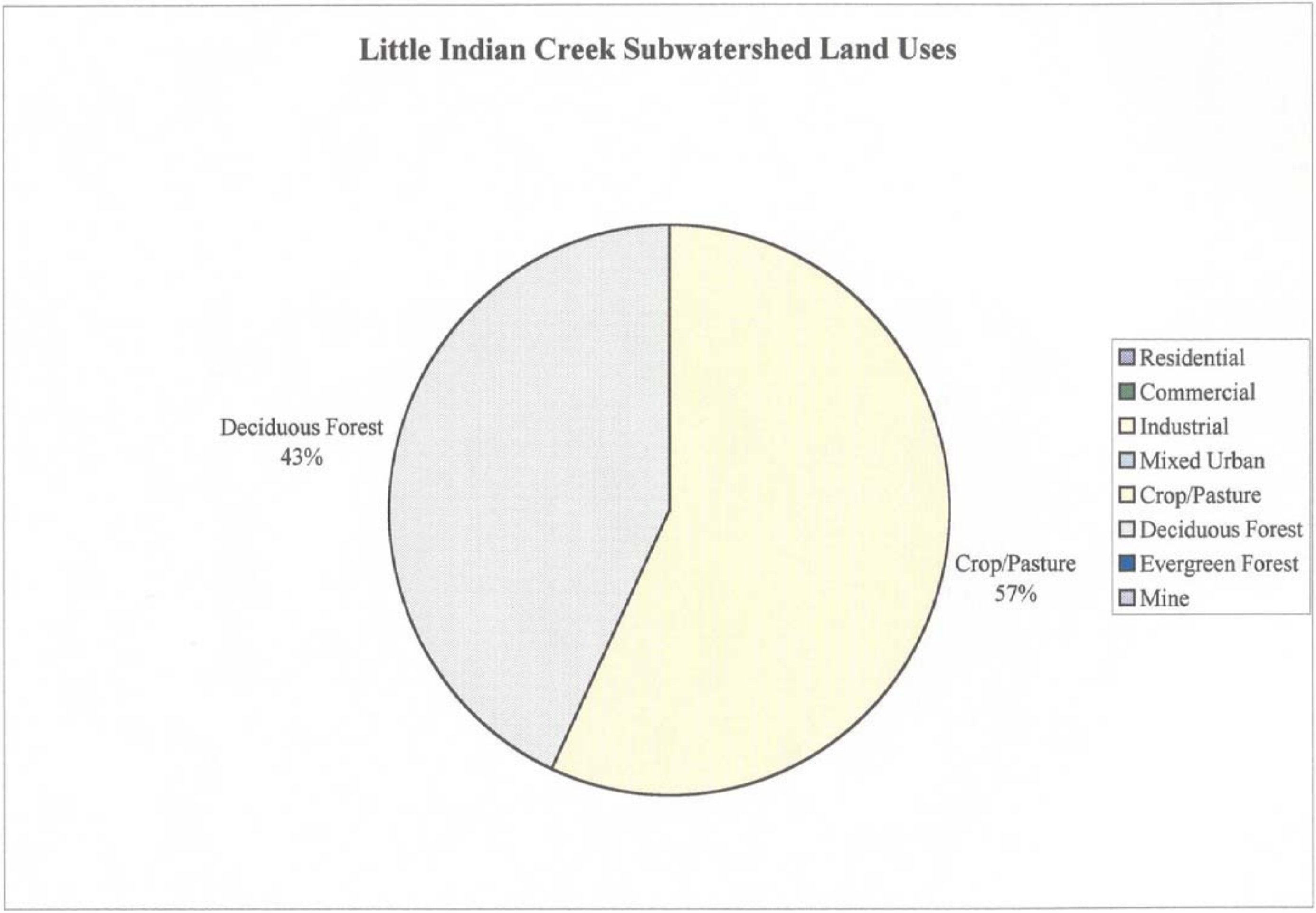
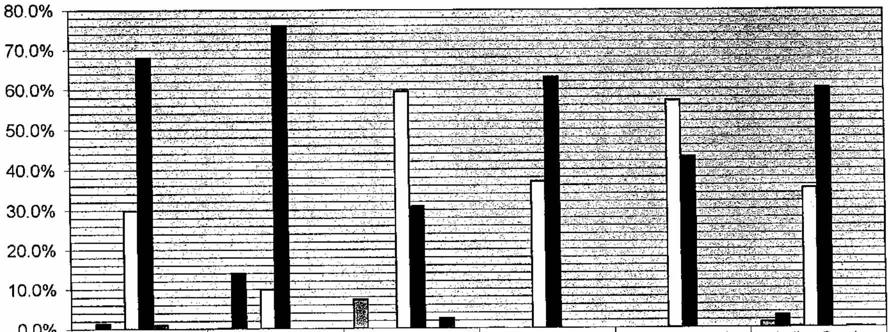

Little Indian Creek Subwatershed Land Uses
Deciduous Forest
43%
Crop/Pasture
57%
Residential
Commercial
Industrial
Mixed Urban
Crop/Pasture
Deciduous Forest
Evergreen Forest
Mine

Figure IV-19

Indian Creek Subwatershed Landuses



	Opossum Ck	Sulphur Ck	Spring Ck	Popcorn Ck	Little Indian Ck	Indian Creek
Residential		0.2%	7.3%	0.1%		1.2%
Commercial	1.3%	13.9%				3.0%
Industrial						0.1%
Crop/Pasture	29.8%	9.9%	59.5%	36.9%	57.1%	35.0%
Deciduous Forest	68.0%	75.9%	30.8%	63.0%	42.9%	60.2%
Evergreen Forest	0.9%					
Mine			2.4%			0.2%
Mixed Urban						0.1%

Subwatershed

determine pollutant loadings from aerial sources and their relation to land uses are listed as follows:

Factors strongly effecting pollution generation and correlated closely with land uses.

- Population density
- Atmospheric fallout
- Degree of impervious surface (usually correlated with population density).
- Vegetative cover
- Street litter accumulation rates.
- Traffic density
- Curb density and height
- Street cleaning practices
- Pollution conveyance systems

Factors strongly effecting pollution generation but correlated poorly with land uses.

- Street surface conditions
- Degree of impervious area directly connected to a channel
- Delivery ratio
- Surface storage
- Organic and nutrient content of soils

Factors strongly effecting pollution generation but unrelated to land uses

- Meteorological factors
- Soil characteristics and composition
- Permeability
- Slope
- Geographical factors

From this list of causative factors it can be seen that many are, in part, correlated to land use. Therefore, attempts to relate pollution loadings from diffuse sources to land use are justified. Factors not related to land use such as slope, soil texture and fertility, drainage density, and vegetative cover are less dominant for urban lands, which primarily have impervious surfaces, than for rural lands. Therefore, it is often easier to relate pollutant generation to land use for urban settings.

Despite its questionable accuracy, the concept of relating pollution loading to land use categories has found wide application in aerated pollution abatement efforts and planning. A simple reason explains this situation; the concept provides a simple mechanism and quick answers to pollutant problems of large areas where more complicated efforts would fail because of the enormous amounts of information required. The land use/pollutant loading concept also is compatible with so-called "overview modeling", whereby unit loadings are combined with information on land use and soil distribution, and other characteristics to yield watershed loadings, or identify areas producing the highest amount of diffuse pollution.

1. Residential land use.

This term applies to a wide variety of urban sections, ranging from subdivisions with 1-acre lots to highly congested urban centers. Residential zones typically are subdivided according to population density into low-density (1 to 6 people/acre), medium density (7 to 20 people/acre) and high-density areas (>21 people/acre). Within the Indian Creek watershed, there are no population centers or towns having wastewater treatment facilities. Therefore, residential areas are comprised of building lots large enough to at least accommodate some sort of on-site septic system. As that is the case, the residential areas, both within the borders of platted towns and outside in rural settings, are low-density areas.

In general, low density, well-maintained residential areas with natural surface runoff drainage systems generate pollutant loadings that are of the same order of magnitude as background loadings from nonagricultural rural lands. However, the on-site septic systems may add significant amounts of pollutants, especially to base flow components. Streams draining low-density residential areas served by septic systems generally have higher nitrogen contents.

2. Commercial land use.

This category covers a broad scale of land use activities that include shopping centers, warehouse storage areas, parking areas, congested downtown commercial zones, and governmental buildings. Within the Indian Creek watershed, areas mapped as commercial land use represent the non-forested areas of the Crane Naval Surface Warfare Center (Crane). The east side of Crane is within the watershed and the non-forested sections of that area are nearly exclusively used for magazines or ammunition/armament bunkers and access roads to them.

The degree of imperviousness of commercial areas is generally medium to high but is believed to be low to medium within this watershed. Magazines, by design, are generally embedded and covered with vegetated soil. Other than buildings in that area, most of the available land is occupied by parking lots and access roads.

Studies from the Pollution from Land Use Activities Reference Group indicated pollution loading from commercial land in the following ranges:

Table IV-8

Parameter	Lb./acre/year
Suspended Solids	45-750
Total Phosphorus	0.1-0.35
Total Nitrogen	1.7-10
Lead	0.15-1.0

3. Industrial Land Use

This category ranges from light manufacturing with relatively low pollution impact to heavy industries such as steel mills, foundries, ore smelting, and cement manufacturing. These activities are potential major pollution hazards to surface waters from nonpoint and point sources. Land use mapping identified two general areas of industrial land use that collectively account for less than 0.2% of the watershed area. These areas are both located at the top of the watershed, where they are likely to have the least impact to Indian Creek.

4. Mine/ Quarry/ Gravel

Within the Indian Creek watershed, the land use mapping identifies limestone quarry operations in Lawrence County. These facilities have the potential to discharge effluent that is characteristically alkaline (high pH) and high in suspended solids. Spring Creek, a tributary of Indian Creek, receives runoff from these operations.

5. Mixed Urban

This category identified by the land use mapping represents a mixture of residential and commercial land use. There is one map unit of mixed urban land, which represents the town of Stanford in Monroe County. Pollutant loading for this area is expected to fall within the range of values presented in Table IV-9 presented for commercial land uses.

Table IV-9
Ranges of Non-point Source Pollutant Loads by Land Use
(Lb/acre/year)
(Source: Sonzogni etal, 1980)

Land Use	Suspended Solids	Total Phosphorus	Total Nitrogen
Rural			
Cropland	18-4550	0.18-4.1	3.8-28
Improved Pasture	27-71	0.1-0.4	2.9-12.5
Forest	1-730	0.02-0.6	1-5.6
Idle	6-730	0.02-0.6	0.4-5.4
Urban			
Residential	550-2050	0.4-1.2	4.5-6.5
Commercial	45-740	0.1-0.8	1.7-9.8
Industrial	400-1517	0.8-3.7	1.7-12.5
Developing urban	24,500	20	56

6. Crop/Pasture

The land use mapping identifies three map units that are rural including crop and pasture land as one unit, deciduous forest, and evergreen forest. Ideally, the assessment of agricultural land would be broken down into separate cropland versus pastureland. The land use mapping did not have that capability therefore the agricultural cropland and pasture are combined as one map unit.

Many factors effect pollutant discharge from farm croplands. Pollutants arise from surface runoff by erosion of topsoil and recently surface applied chemicals, through interflow, which is tile drainage water, and groundwater base flow. Often the reduction of one component of pollution results in an increase in other components. Erosion and soil loss by surface runoff is considered a predominant source of pollution from croplands. The disturbing activity associated with tillage substantially increases the erosion potential of croplands. On the other hand, increased hydrologic surface storage and permeability of tilled fields reduce hydrologic activity, which sometimes balances the increased erosion potential.

Regarding the nutrient loss of N and P, over 90% is associated with soil loss. Nutrient losses usually represent only a small fraction of the applied fertilizer and often are economically insignificant. Nevertheless, their pollution impact almost always exceeds the standards accepted for preventing accelerated eutrophication of surface waters.

Pasture used directly for livestock production and grazing practices include continuous and seasonal or rotational grazing. Unit loads of most pollutants from pasture are at least an order of magnitude less than loads from cropland areas. Generally, pastures are considered nonhazardous land uses requiring little or no pollution control. When cattle are allowed close proximity or access to a watercourse however, pasture may become a pollution hazard.

Renovation practices on pastures, including mechanical and chemical methods, improve grass quality and density, and reduce soil loss. Converting hazardous agricultural lands to pasture may be a possible control strategy.

7. Forest

Undisturbed forest or woodland represents the best protection of lands from sediment and pollutant losses. Woodlands and forests have low hydrologic activity due to high surface water storage and interception in leaves, soil, mulch, and surface roughness. Furthermore, forest soils frequently have improved permeability. Even lowland forest with a high groundwater table absorb large amounts of precipitation and actively retain and retard runoff. In addition, tree canopy and ground covers reduce surface impact and encourage infiltration. The increased organic content of forest soils significantly reduces erosion losses such that surface runoff from forested areas is often almost nonexistent.

Streams draining lowland forests, however, may have elevated organic and nutrient levels caused by leaching from soils by interflow and base flow. Despite this effect, woodlands are generally regarded as the determinants to background pollution levels against which other land uses are judged.

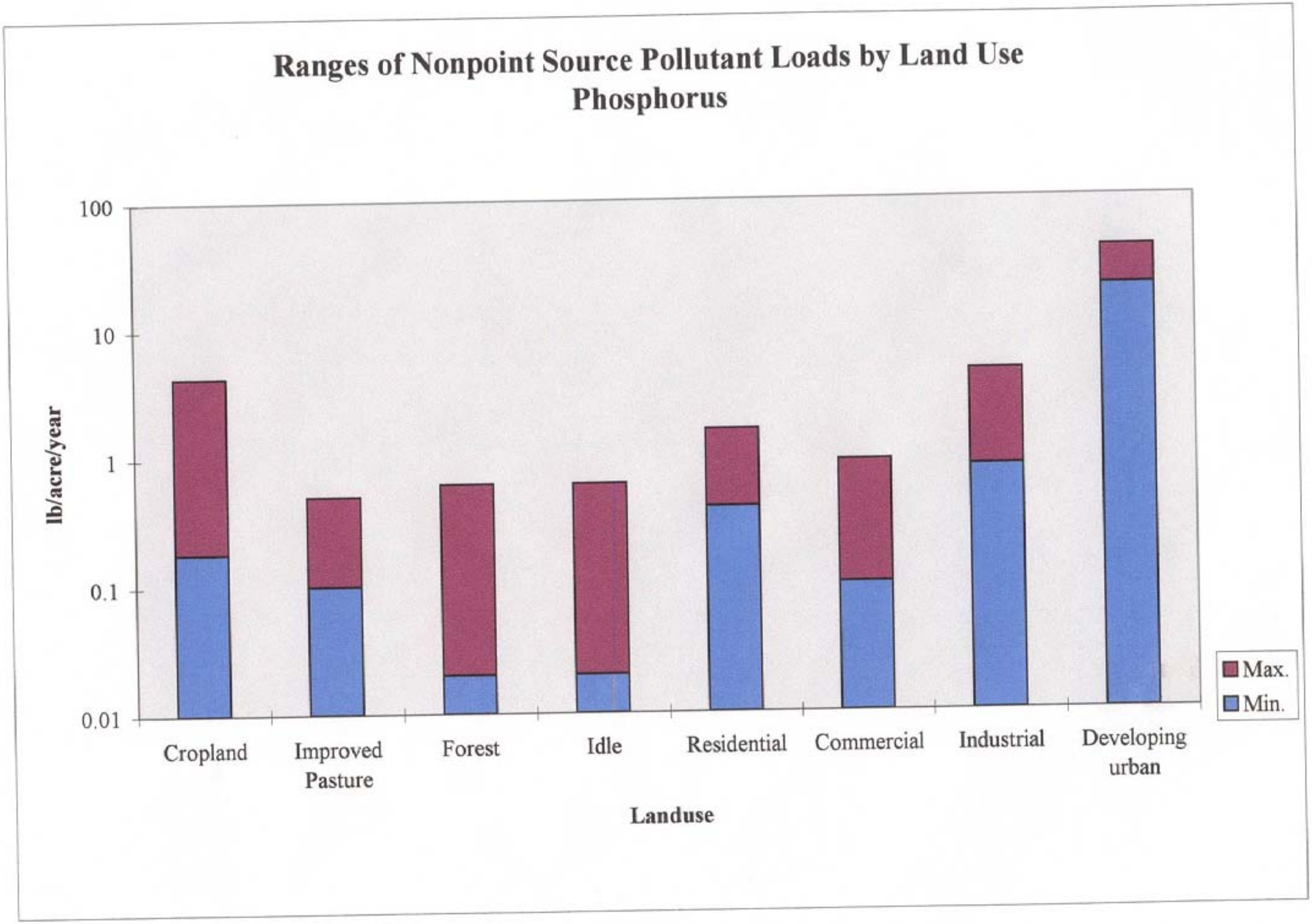

Ranges of Nonpoint Source Pollutant Loads by Land Use
Phosphorus
100
10
1
0.1
0.01
lb/acre/year
Cropland
Improved Pasture
Forest
Idle
Residential
Commercial
Industrial
Developing urban
Landuse
Max.
Min.

Figure IV-21

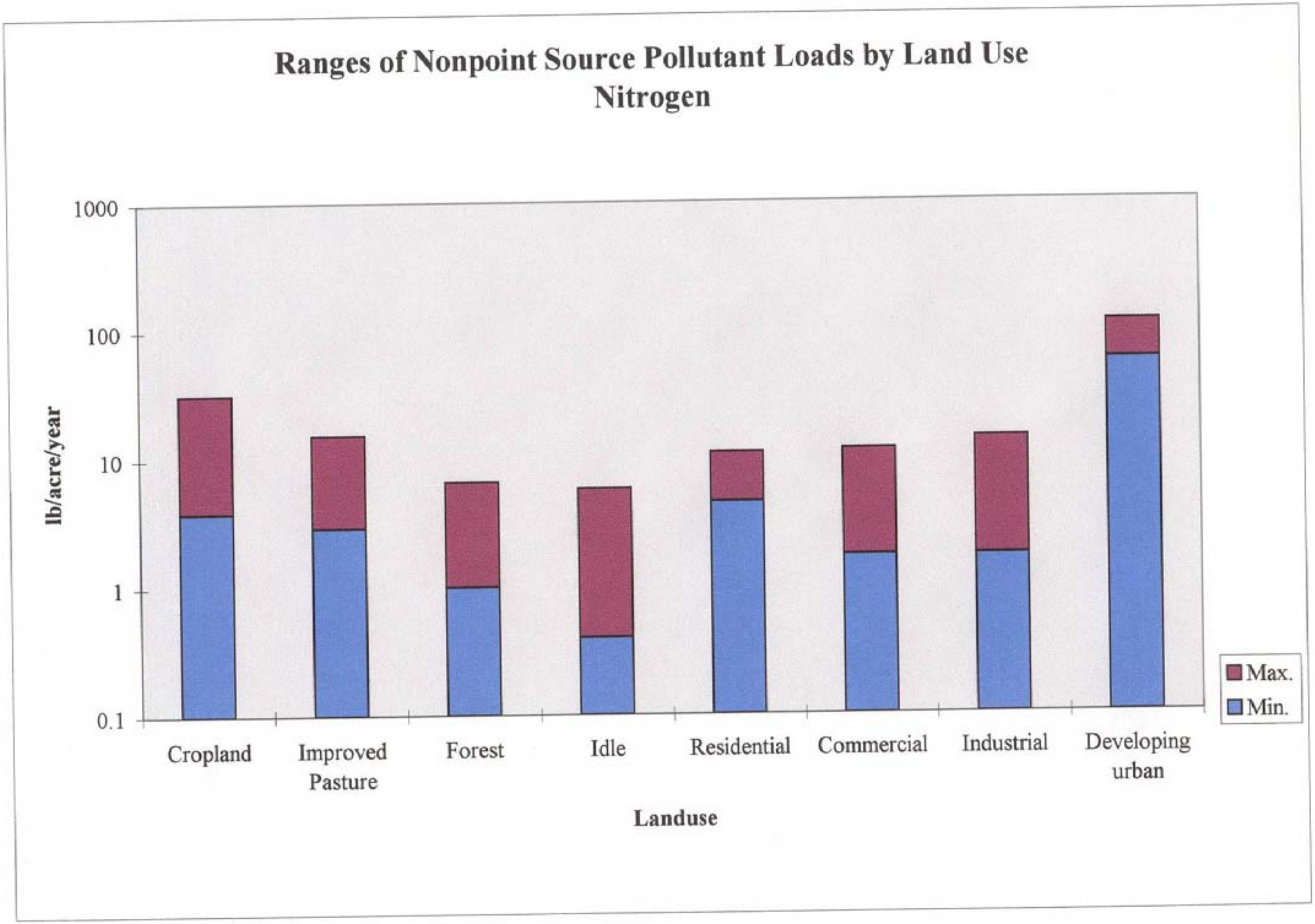
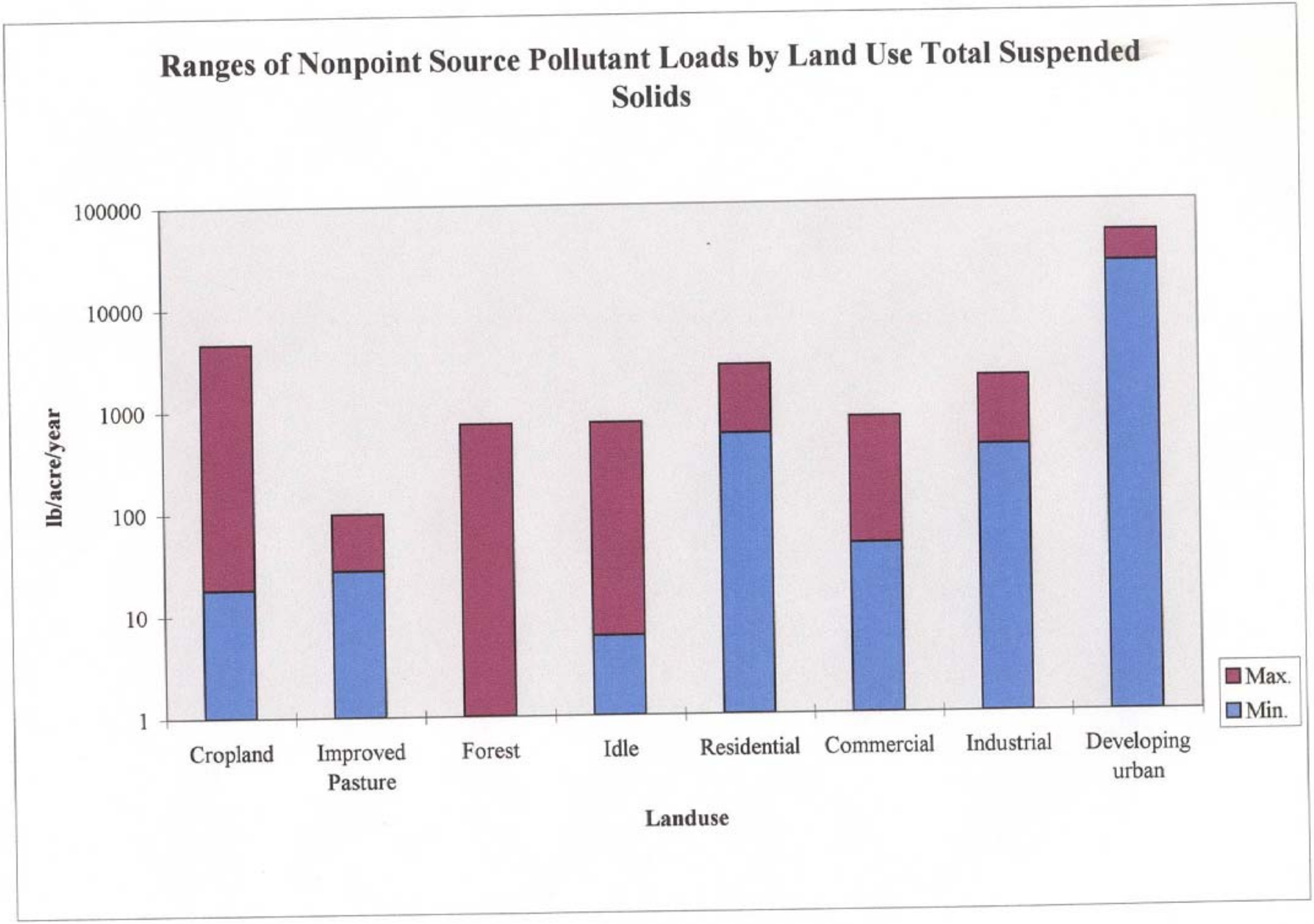

Ranges of Nonpoint Source Pollutant Loads by Land Use
Nitrogen
1000
100
10
1
0.1
lb/acre/year
Cropland
Improved Pasture
Forest
Idle
Residential
Commercial
Industrial
Developing urban
Landuse
Max.
Min.

Figure IV-22


Ranges of Nonpoint Source Pollutant Loads by Land Use Total Suspended Solids
lb/acre/year
100000
10000
1000
100
10
1
Cropland
Improved Pasture
Forest
Idle
Residential
Commercial
Industrial
Developing urban
Landuse
Max.
Min.

Uncontrolled logging operations, including clearcutting, often disturb the forest's resistance to erosion. In many situations, almost all sediment reaching waterways from forestlands originates from construction of logging roads and/or from clearcuts. Logging roads that disrupt or infringe upon natural drainage channels are primary sources of sediment.

6. Streambank Erosion

Streambank erosion is the direct removal of banks and beds by flowing water. Typically, it occurs during periods of high stream flow. It is sometimes confused with gully erosion as this has similarities with seasonal or ephemeral streams.

Erosion of stream or riverbanks through lateral (side) erosion and collapse often causes high sediment loads in creeks and rivers. The problem is often initiated by heavy falls of rain in catchments with poor vegetation cover, causing excess run-off. The resultant high volume and velocity runoff will concentrate in the lower drainage lines or streams within catchments. When the stress applied by these stream flows exceeds the resistance of the local soil material, streambank erosion occurs. As the sediment load increases, fast-flowing streams grind and excavate their banks lower in the landscape. Later, the stream becomes overloaded or velocity is reduced, and deposition of sediment takes place further downstream. Streambank erosion is exacerbated by the lack of riparian zone vegetation and by direct stock access to streams.

In addition to loss of productive land due to bank erosion, dramatic changes in the course of a creek often restrict access on properties. Subsequent deposition of soil causes problems on productive land downstream and sedimentation in reservoirs. Other problems include reduction in water quality due to high sediment loads, loss of native aquatic habitats, damage to public utilities (roads, bridges and dams) and maintenance costs associated with trying to prevent or control erosion sites.

Catchments with little vegetation cover and steep gradients will often have high rates of water run-off that result in high-velocity stream flows. Stream straightening, dredging or realignment to accommodate roads lines leads to increased stream power and velocity, which in turn will increase the energy applied to stream banks. The erosive impact of these high-velocity stream flows will depend on the stability of the bank material. For instance, sand will erode more easily than gravel and silt will erode more easily than sand.

In grazing areas the summer dieback of annual pasture species exposes the soil to rainfall and thunderstorms. Consequent high run-off will result in high-velocity stream flows. Along poorly vegetated stream banks, obstructions such as dead trees can divert water flows initiating erosion downstream, while rocks, roots and tree stumps create turbulence that may initiate erosion at 'nick points' in the bank. Look for subsequent high sediment loads in streams, and lateral streambank erosion collapse and retreat.

Creeks or streams may change direction or cut new channels very rapidly in storms, while over longer periods they may change course. Sediments deposited in lower-flow periods may obstruct the natural flow of streams or ultimately fill reservoirs.

Reduce run-off by replacing vegetation and keeping cover levels high. Store water in the catchment for as long as possible by maintaining high vegetation cover and employing engineering measures such as retarding dams. Limit stock access to stream frontages and encourage revegetation of banks and creek lines.

V. STREAM CORRIDOR

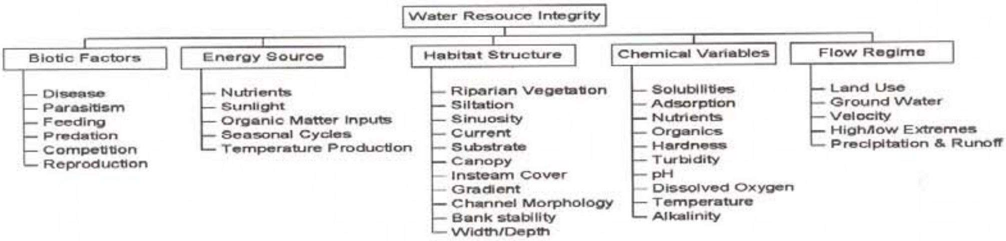
A stream is a complex ecosystem in which several biological, physical, and chemical processes interact. Changes in any one characteristic or process have cascading effects throughout the system and result in changes to many aspects of the system.

Some of the factors that influence and determine the integrity of streams are shown in Figure V-1. Often times several factors can combine to cause profound changes. For example, increased nutrient loading alone may not cause a change to a forested stream, however, when combined with tree removal and channel widening, the result can shift the energy dynamics from an aquatic biological community based on leaf litter inputs to one based on algae and macrophytes.

Many stream processes are in a delicate balance. Hydrologic changes, for example, that increase stream flow, if not balanced by greater channel complexity and roughness, result in flow that erodes banks or the stream bottom. Increases in sediment load beyond the transport capacity of the stream, on the other hand, leads to deposition, lateral channel movement into streambanks, and channel widening.

Most systems would benefit from increased complexity and diversity in physical structure. Structural complexity is provided by trees falling into the channel, overhanging banks, roots extending into the flow, pools and riffles, overhanging vegetation, and a variety of bottom materials. This complexity enhances habitat for organisms and also restores hydrologic properties that often have been lost.

Figure V-1
Factors that Influence the Integrity of Streams



Characterization of the water quality of Indian Creek was performed in accordance with established guidelines recommended by the Lake and River Enhancement Program. Ten sampling points were selected at mouths of significant sub-watersheds and within Indian Creek proper. These points were selected by the consultant in concert with Natural Resources personnel at the State and Federal level (including Lake and River Enhancement Program personnel and local Soil and Water Conservation District personnel). There were seven named tributaries and three sites located within Indian Creek selected to represent water quality in the watershed. These locations were selected based on historical and current conditions in the various sub-watersheds, the proportion of the Indian Creek watershed represented by the tributary, and civil boundaries. The following table summarizes the significant features of each of the sampling locations.

Table V-1
Indian Creek Watershed Sampling Points

Sample Point	Location	Quadrangle	County	Representing
1	Opossum Creek	Indian Springs	Martin	Dover Hill, Crane, Ag land, Cattle
2	Sulphur Creek	Indian Springs	Martin	Indian Springs, Cale, Crane(ABG), Little Sulphur Creek
3	Indian Creek	Williams	Martin	Lower Watershed, Lawrence County wetlands
4	Padanaram	Williams	Martin	Sulphur Creek, Padanaram Commune, Crane
5	Indian Creek	Williams	Lawrence	Middle Watershed, Silverville, Ag land, Cattle
6	Spring Creek	Owensburg	Lawrence	Springville, Cattle
7	Town Branch	Owensburg	Greene	Silverville, Crane
8	Popcorn Creek	Owensburg	Lawrence	Popcorn, Cattle
9	Little Indian Creek	Stanford	Greene	Ag Land, Cattle
10	Indian Creek	Stanford	Monroe	Stanford, Residential

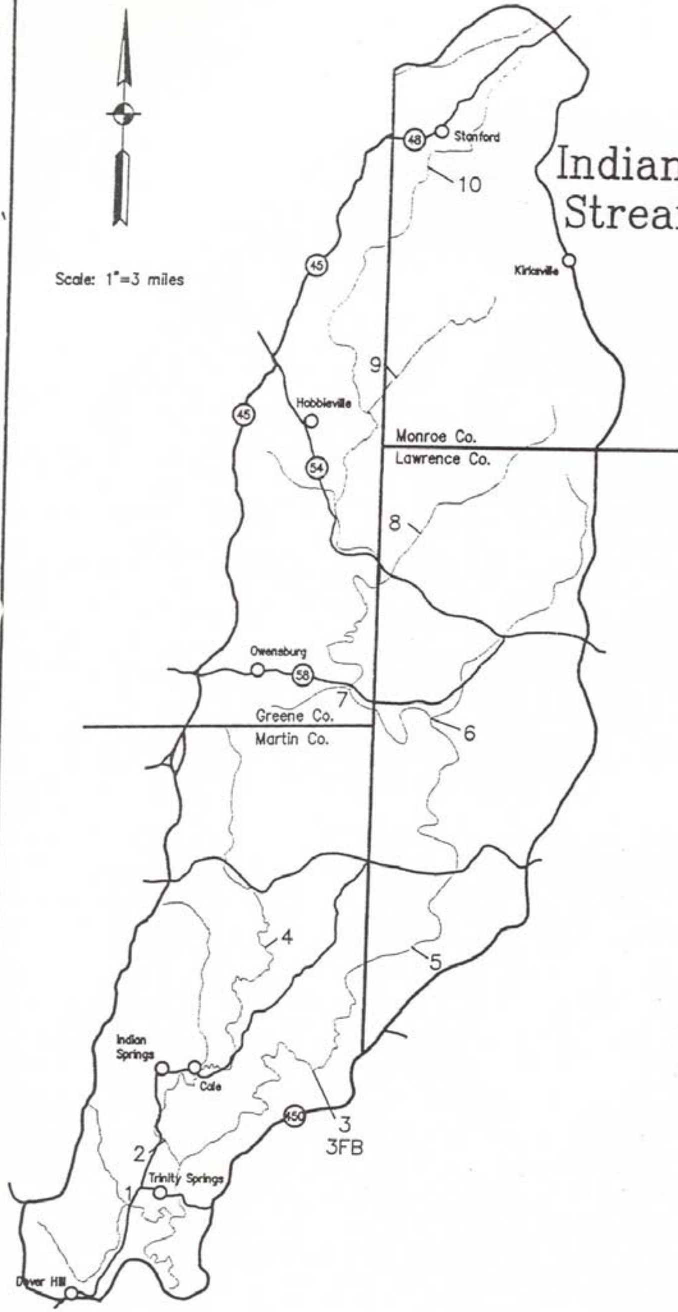
At each site, data on water quality was collected and analyzed according to the recommended parameters. A field blank was also analyzed in the laboratory to validate the detected levels of the various contaminants and this blank was identified as 3FB. The prepared containers were filled with deionized water, provided by the laboratory, at sample point number 3 and then handled in every way in a manner consistent with the other sample containers. In addition, the quality of biological communities was assessed relying, in part, on the Rapid Bioassessment Protocol II method. The quality of the stream and riparian habitat was evaluated and indexed by implementing the Qualitative Habitat Evaluation Index.

1. Chemical & Physical Quality

At each of the ten sites, water chemistry was evaluated during a fall rain event. Physical and chemical water quality parameters included:

- Dissolved Oxygen
- pH
- Conductivity
- Turbidity
- Temperature
- Nitrate N
- Nitrite N
- Ammonia N
- Total Kjeldahl Nitrogen (TKN)
- Total Phosphorus
- Ortho-Phosphate
- TSS (Total Suspended Solids)

Indian Creek Watershed Stream Sampling Sites



Station Location

1	Opossum Ck
2	Sulfur Ck
4	Padanaram
6	Spring Ck
7	Town Br
8	Popcorn Ck
9	Lil Indian Ck
3FB	Indian Ck
3	Indian Ck
5	Indian Ck
10	Indian Ck

FIGURE V-2

Figure V-3
Indian Creek Water Quality

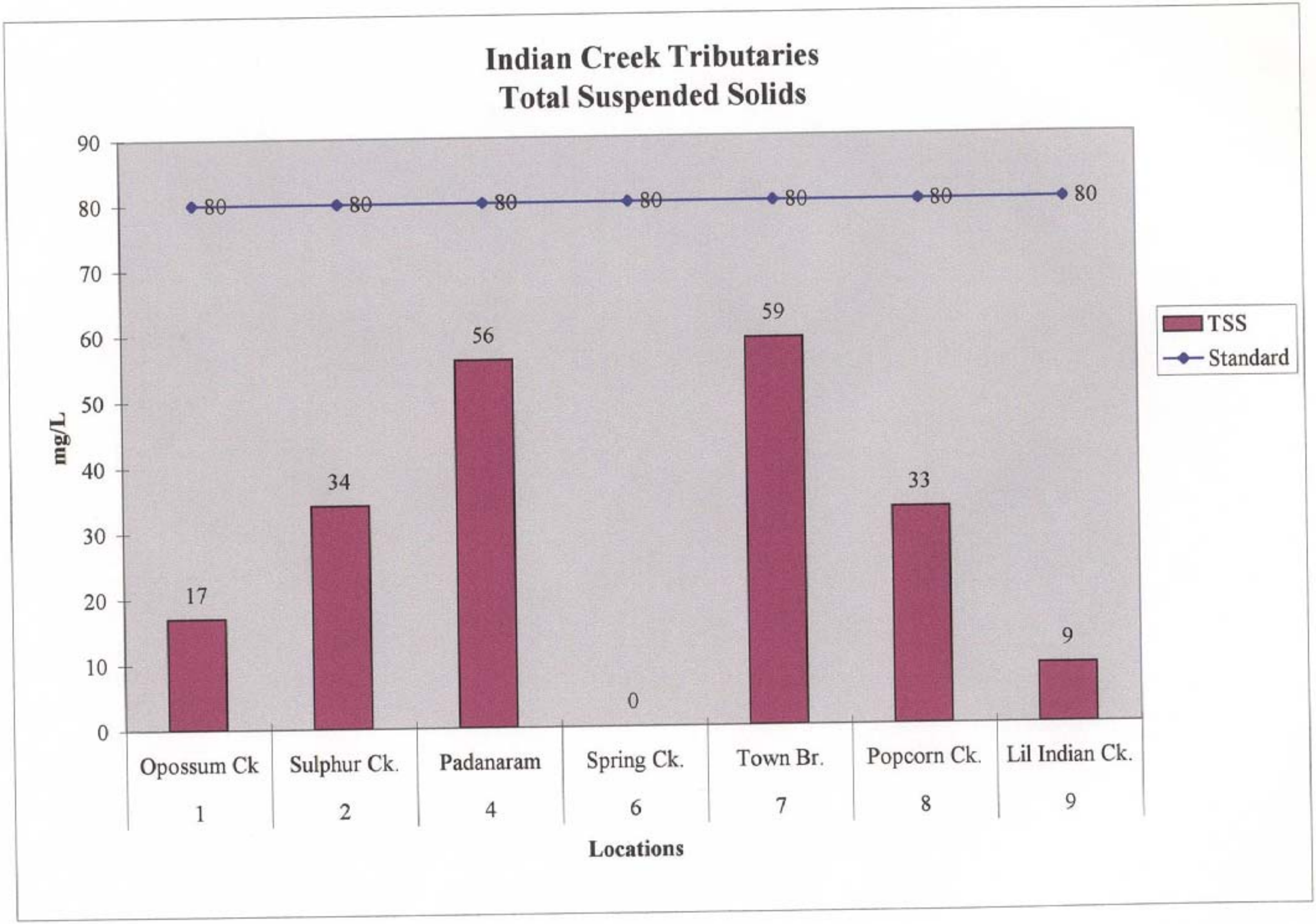
Tributaries

Station	Location	pH	Conductivity (mS/m)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Temp. (C)	Nitrate N (mg/L)	Nitrite N (mg/L)	Ammonia N (mg/L)	Total P (mg/L)	TKN (mg/L)	O-Phosphate (mg/L)	TSS (mg/L)
1	Opossum Ck	7.98	0.443	65	7.05	17	0.83	BDL	BDL	0.13	BDL	BDL	17
2	Sulphur Ck.	8.32	0.464	98	4.54	14	0.29	BDL	BDL	0.14	0.7	BDL	34
4	Padanaram	8.29	0.314	204	4.3	18	BDL	BDL	BDL	0.13	0.5	BDL	56
6	Spring Ck.	8.84	0.399	24	4.42	17	0.51	BDL	BDL	0.15	BDL	BDL	BDL
7	Town Br.	8.82	0.268	179	5.26	16	1.4	BDL	BDL	0.21	0.5	BDL	59
8	Popcorn Ck.	8.75	0.555	153	1.53	17	BDL	BDL	11.7	0.71	15.8	BDL	33
9	Lil Indian Ck.	8.7	0.241	61	4.9	16	0.74	BDL	BDL	0.33	1.1	0.19	9

Indian Creek

Station	Location	pH	Conductivity (mS/m)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Temp. (C)	Nitrate N (mg/L)	Nitrite N (mg/L)	Ammonia N (mg/L)	Total P (mg/L)	TKN (mg/L)	O-Phosphate (mg/L)	TSS (mg/L)
3FB	Indian Ck.	7.83	0.001	8	4.48	20	BDL	BDL	BDL	BDL	BDL	BDL	BDL
3	Indian Ck.	8.37	0.397	44	3.23	18	0.26	BDL	BDL	0.1	BDL	BDL	12
5	Indian Ck.	8.3	0.396	34	3.5	18	BDL	BDL	BDL	0.1	BDL	BDL	11
10	Indian Ck.	8.94	0.314	52	5.75	16	1.4	BDL	BDL	0.27	BDL	0.14	13

Figure V-4



Indian Creek Tributaries
Total Suspended Solids
90
80
70
60
50
40
30
20
10
0
mg/L
80
80
80
80
80
80
80
17
34
56
0
59
33
9
TSS
Standard
Opossum Ck
1
Sulphur Ck.
2
Padanaram
4
Spring Ck.
6
Town Br.
7
Popcorn Ck.
8
Lil Indian Ck.
9
Locations

Figure V-5

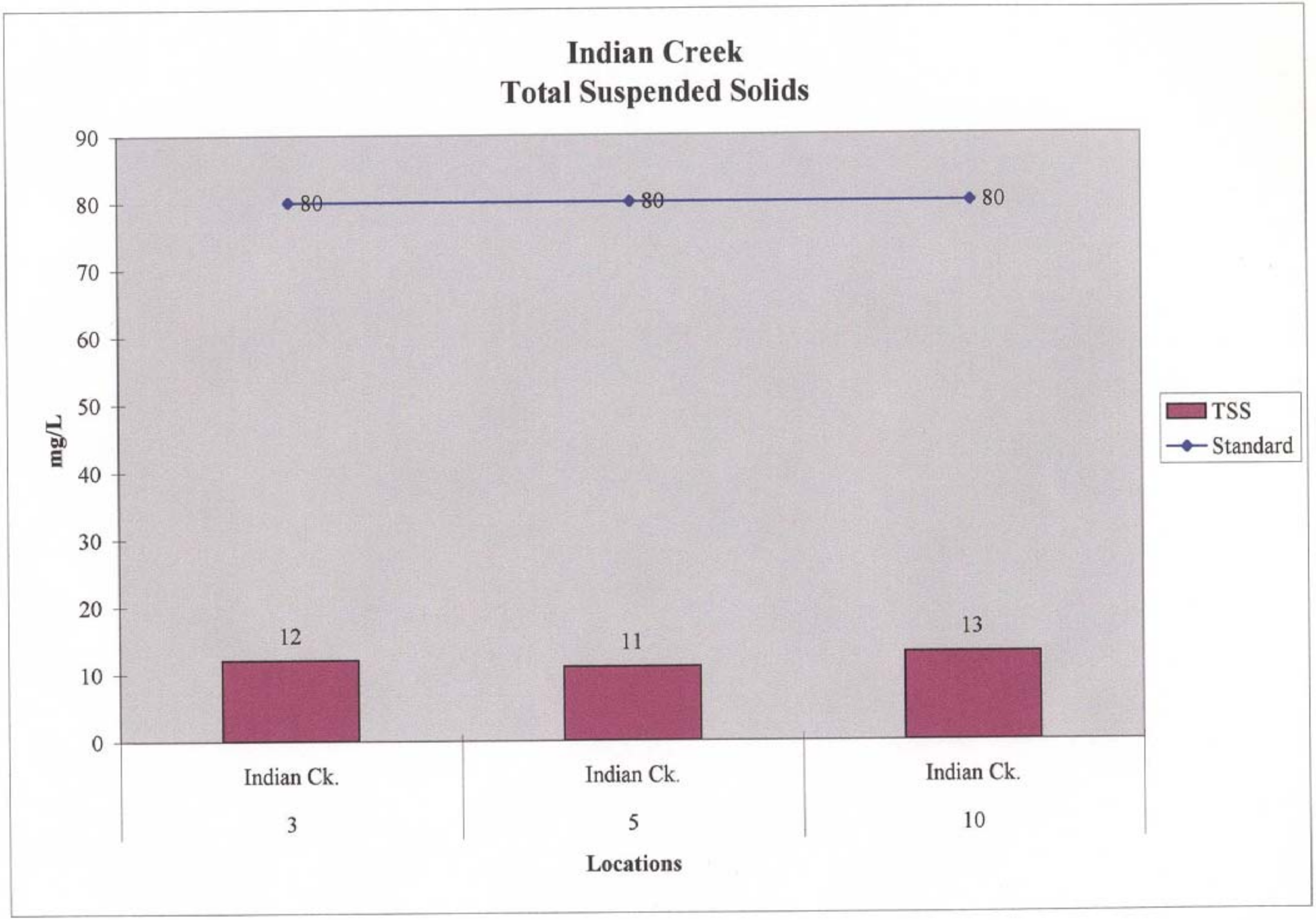

Indian Creek
Total Suspended Solids
90
80
70
60
50
40
30
20
10
0
mg/L
80
80
80
12
11
13
TSS
Standard
Indian Ck.
3
Indian Ck.
5
Indian Ck.
10
Locations

Figure V-6

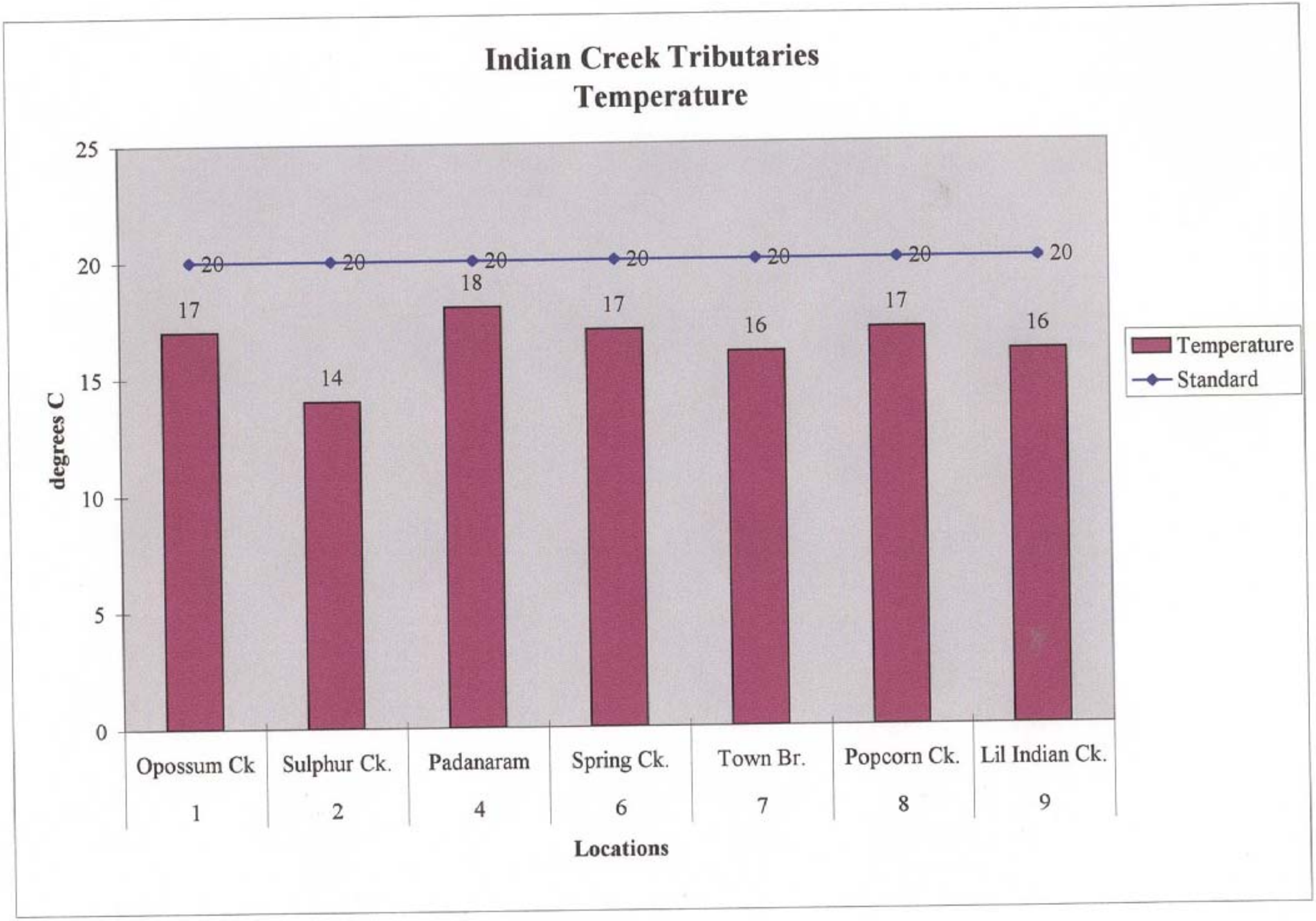
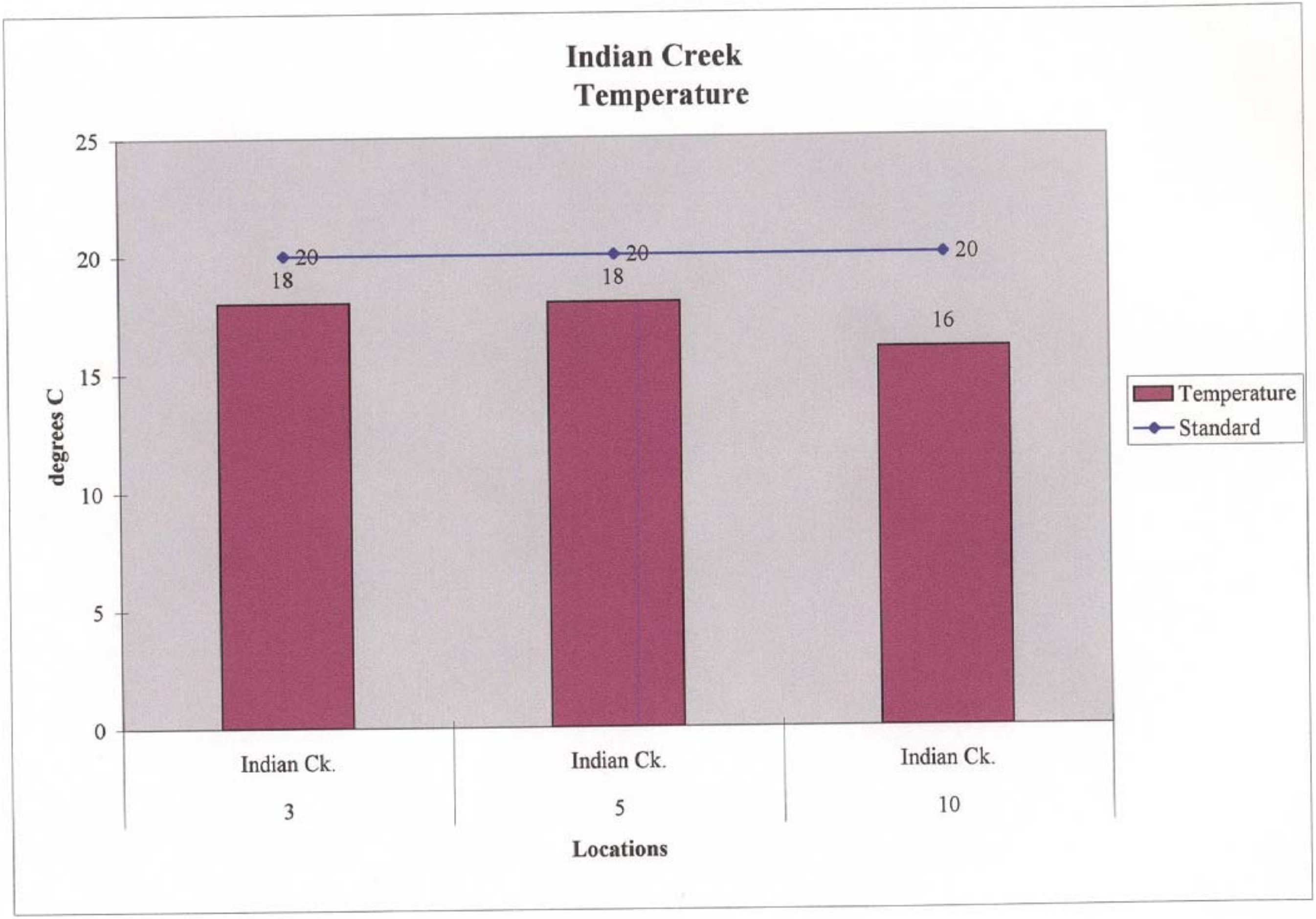
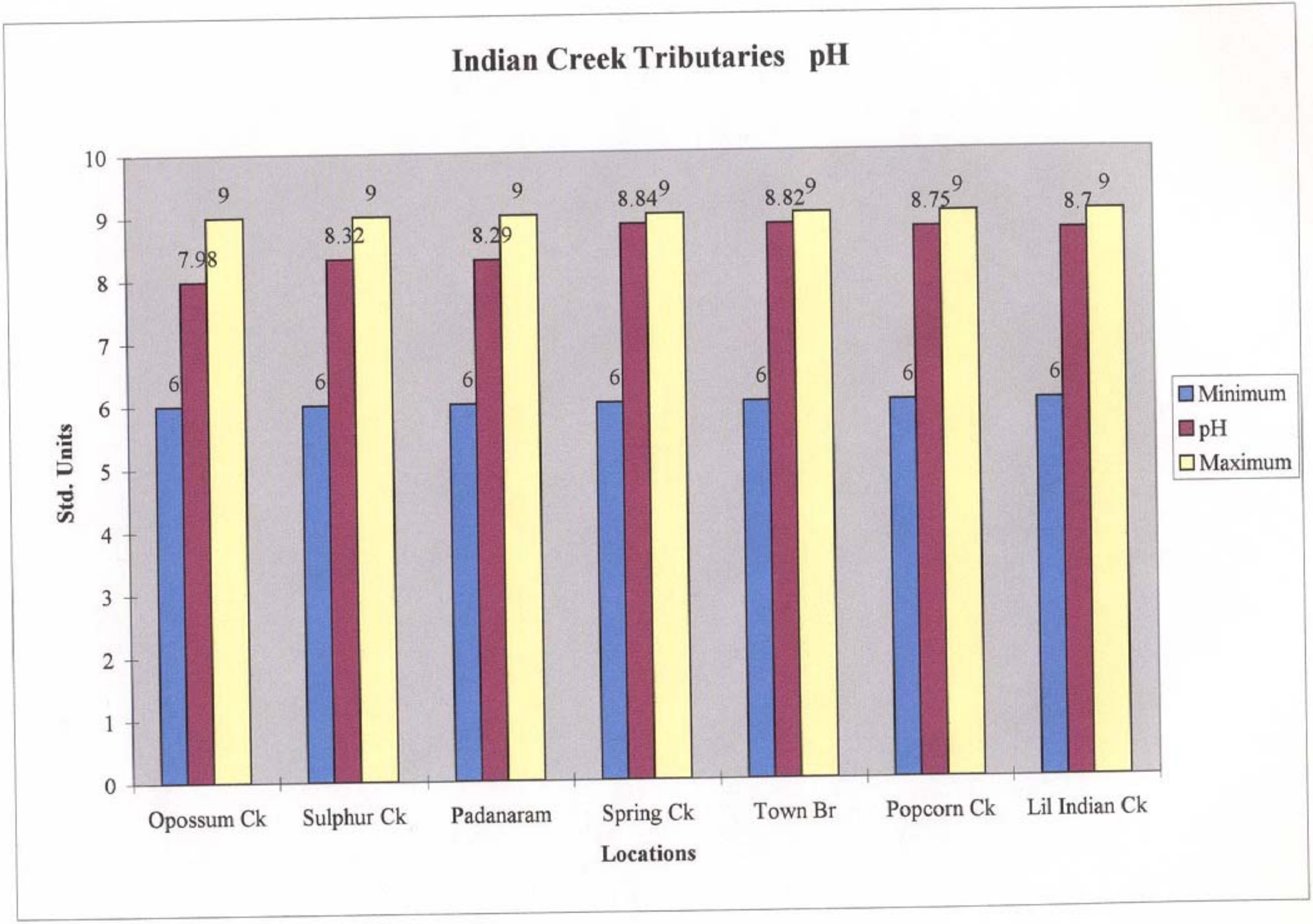

Indian Creek Tributaries
Temperature
25
20
15
10
5
0
degrees C
20
20
20
20
20
20
20
17
14
18
17
16
17
16
Temperature
Standard
Opossum Ck
1
Sulphur Ck.
2
Padanaram
4
Spring Ck.
6
Town Br.
7
Popcorn Ck.
8
Lil Indian Ck.
9
Locations

Figure V-7



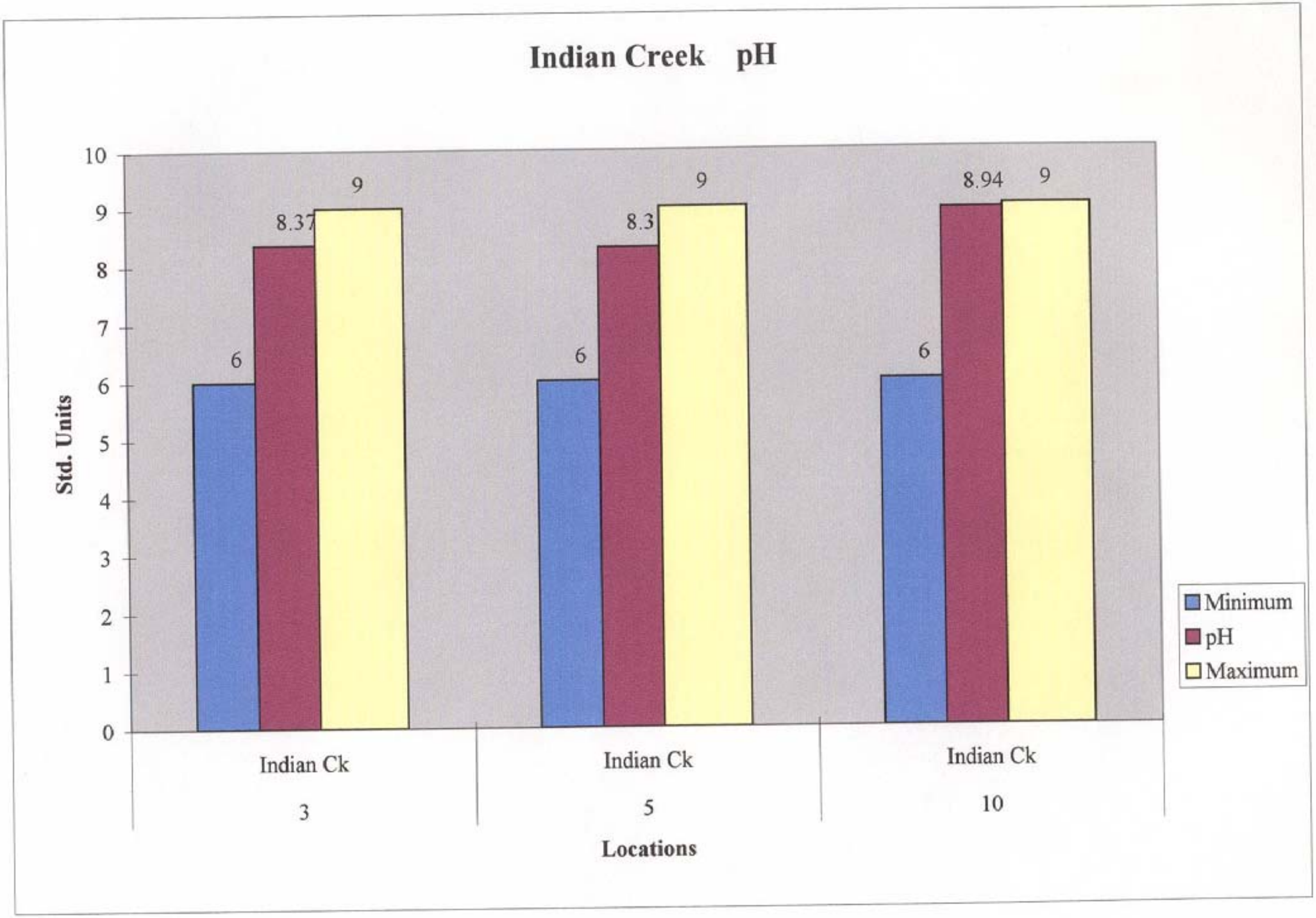
Indian Creek
Temperature
25
20
15
10
5
0
degrees C
20
20
20
18
18
16
Temperature
Standard
Indian Ck.
3
Indian Ck.
5
Indian Ck.
10
Locations

Figure V-8



Indian Creek Tributaries pH
Std. Units
10
9
8
7
6
5
4
3
2
1
0
9
7.98
6
9
8.32
6
9
8.29
6
8.84
9
6
8.82
9
6
8.75
9
6
8.7
9
6
Opossum Ck
Sulphur Ck
Padanaram
Spring Ck
Town Br
Popcorn Ck
Lil Indian Ck
Locations
Minimum
pH
Maximum

Figure V-9


Indian Creek pH
10
9
8
7
6
5
4
3
2
1
0
Std. Units
6
8.37
9
6
8.3
9
6
8.94
9
Indian Ck
3
Indian Ck
5
Indian Ck
10
Locations
Minimum
pH
Maximum

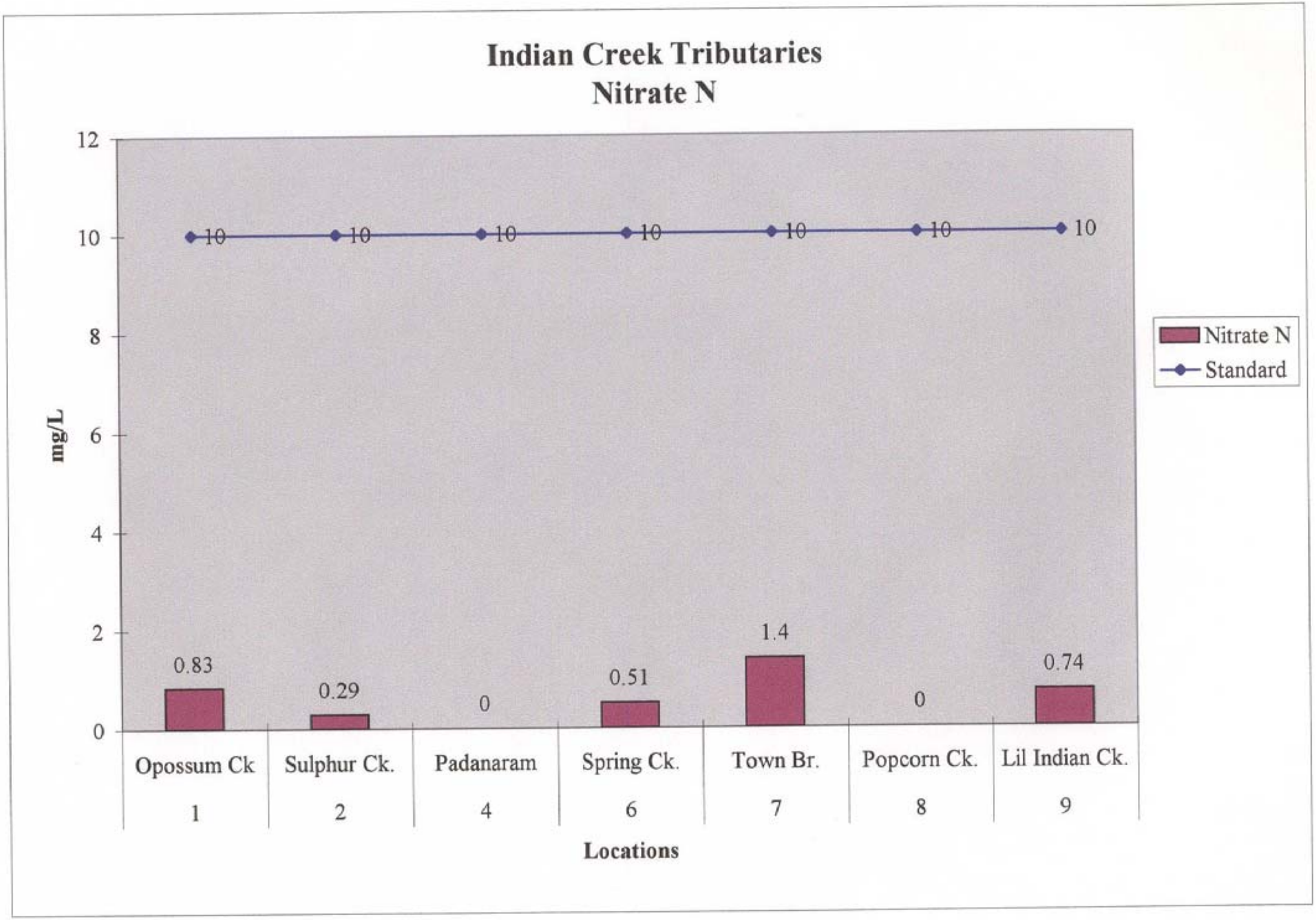
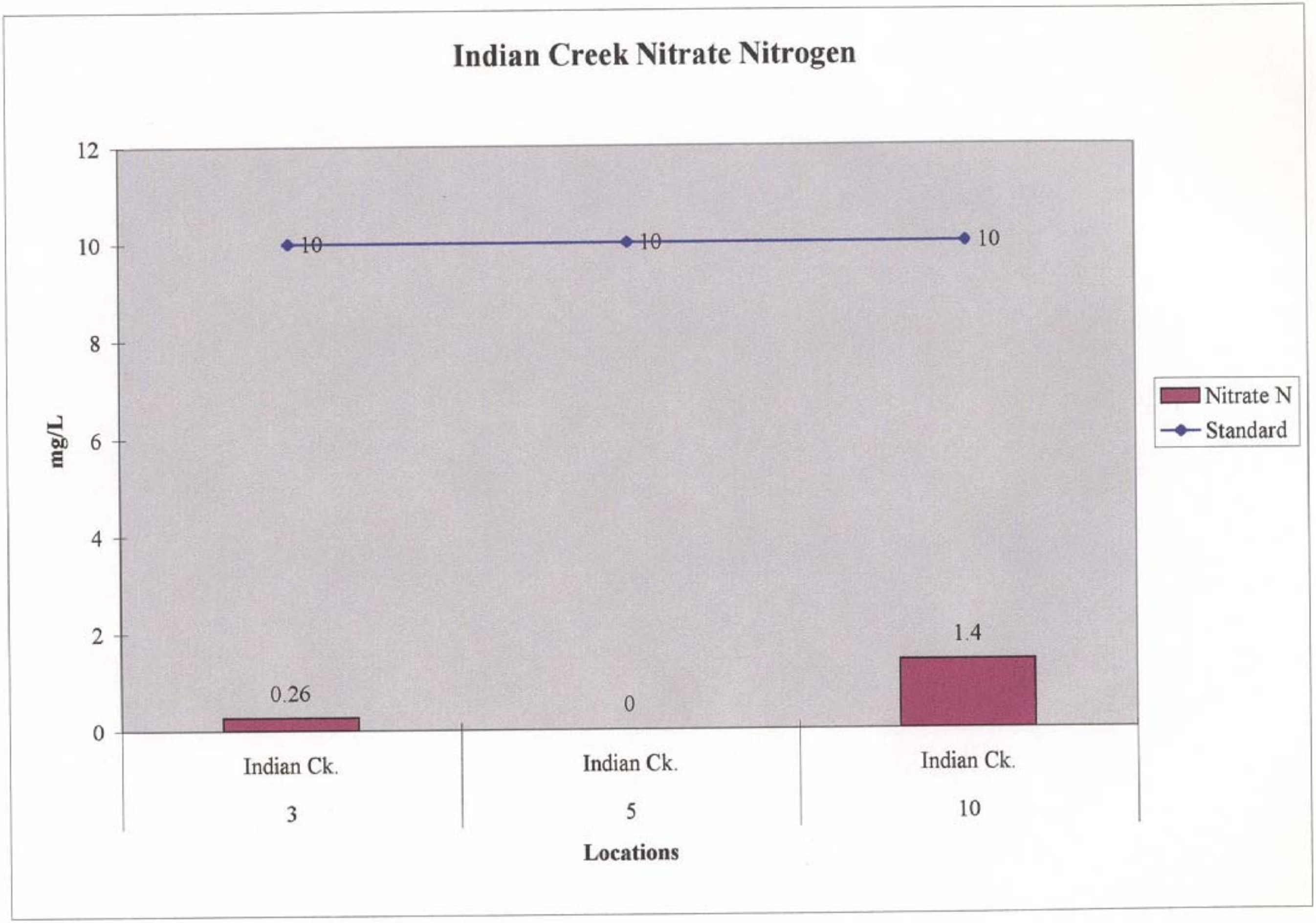

Indian Creek Tributaries
Nitrate N
mg/L
12
10
8
6
4
2
0
10
10
10
10
10
10
10
0.83
0.29
0
0.51
1.4
0
0.74
Opossum Ck
Sulphur Ck.
Padanaram
Spring Ck.
Town Br.
Popcorn Ck.
Lil Indian Ck.
1
2
4
6
7
8
9
Locations
Nitrate N
Standard

Figure V-11



Indian Creek Nitrate Nitrogen
12
10
8
6
4
2
0
mg/L
10
10
10
0.26
0
1.4
Indian Ck.
3
Indian Ck.
5
Indian Ck.
10
Locations
Nitrate N
Standard

Figure V-12

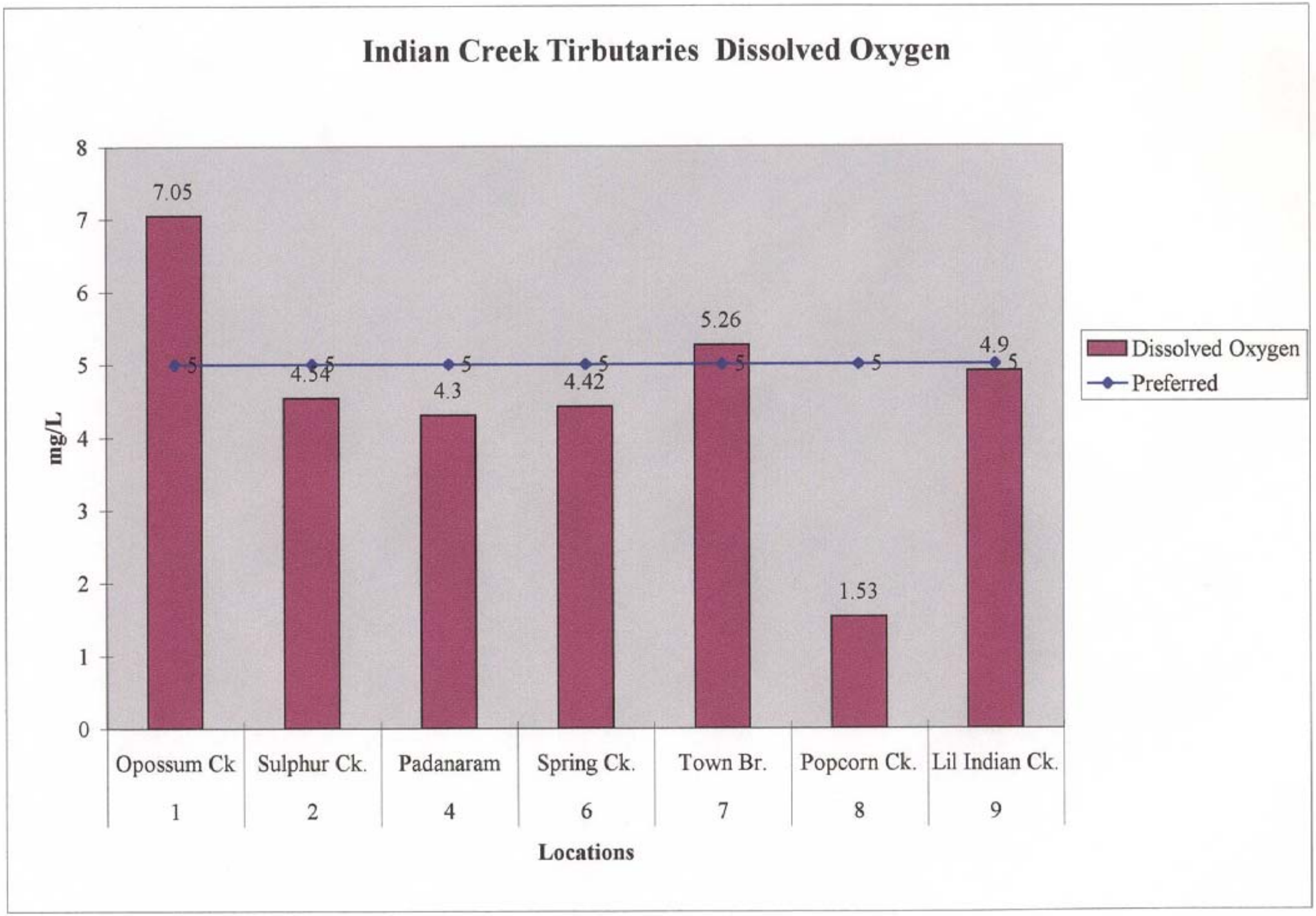
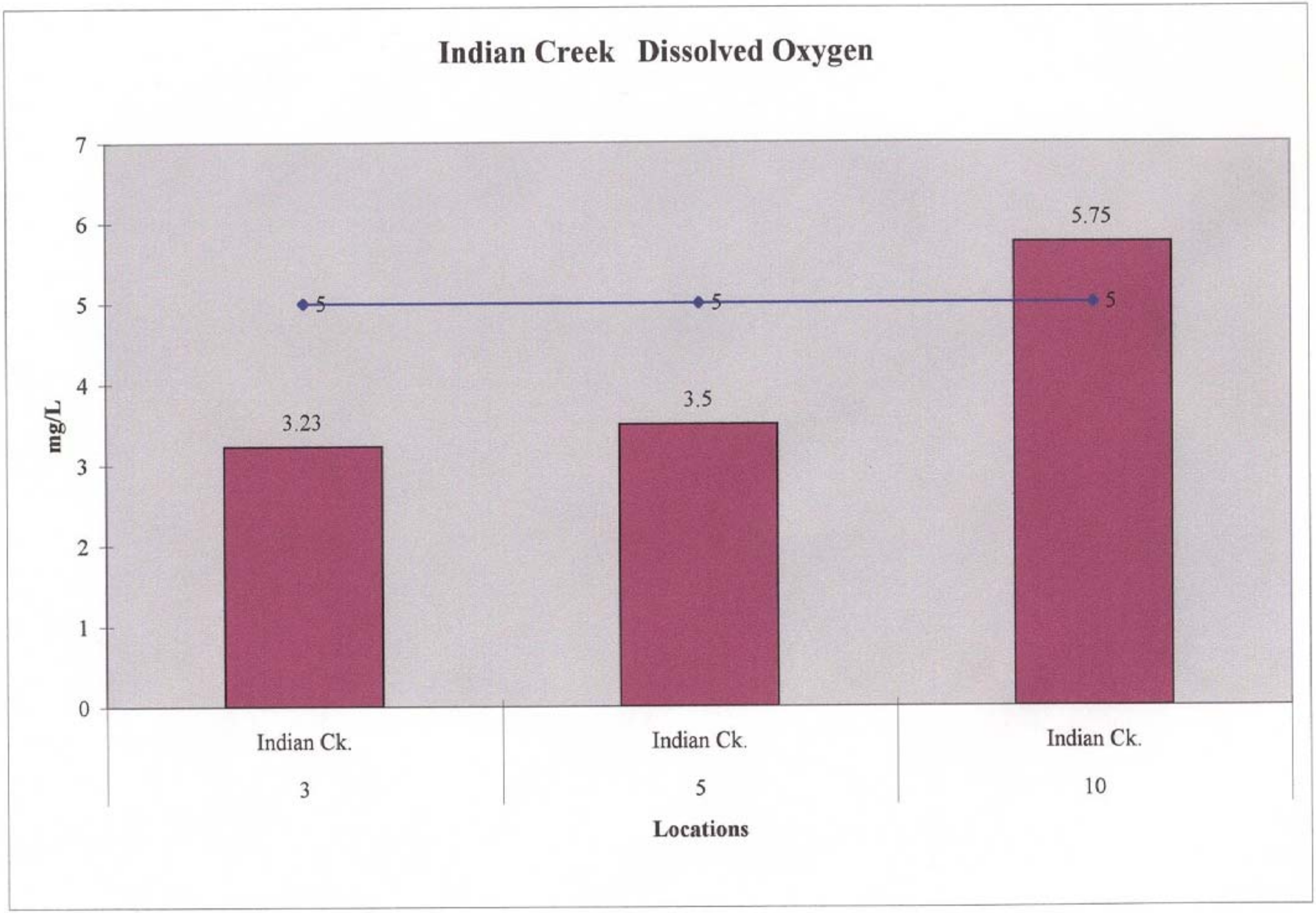

Indian Creek Tirbutaries Dissolved Oxygen
8
7
6
5
4
3
2
1
0
mg/L
7.05
4.54
4.3
4.42
5.26
1.53
4.9
5
Opossum Ck
1
Sulphur Ck.
2
Padanaram
4
Spring Ck.
6
Town Br.
7
Popcorn Ck.
8
Lil Indian Ck.
9
Locations
Dissolved Oxygen
Preferred

Figure V-13



Indian Creek Dissolved Oxygen
7
6
5
4
3
2
1
0
mg/L
5.75
5
5
5
3.5
3.23
Indian Ck.
3
Indian Ck.
5
Indian Ck.
10
Locations

Figure V-14

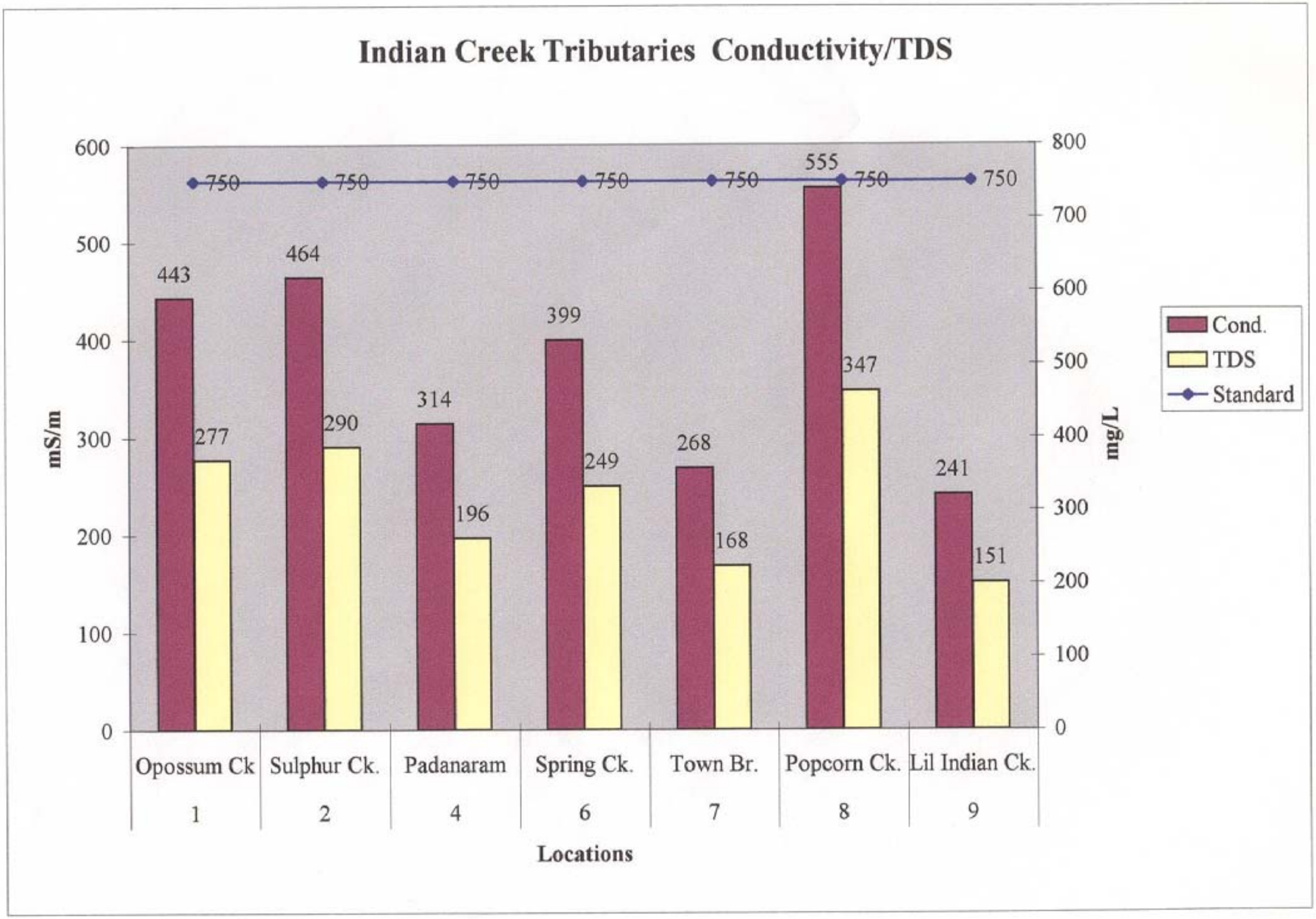
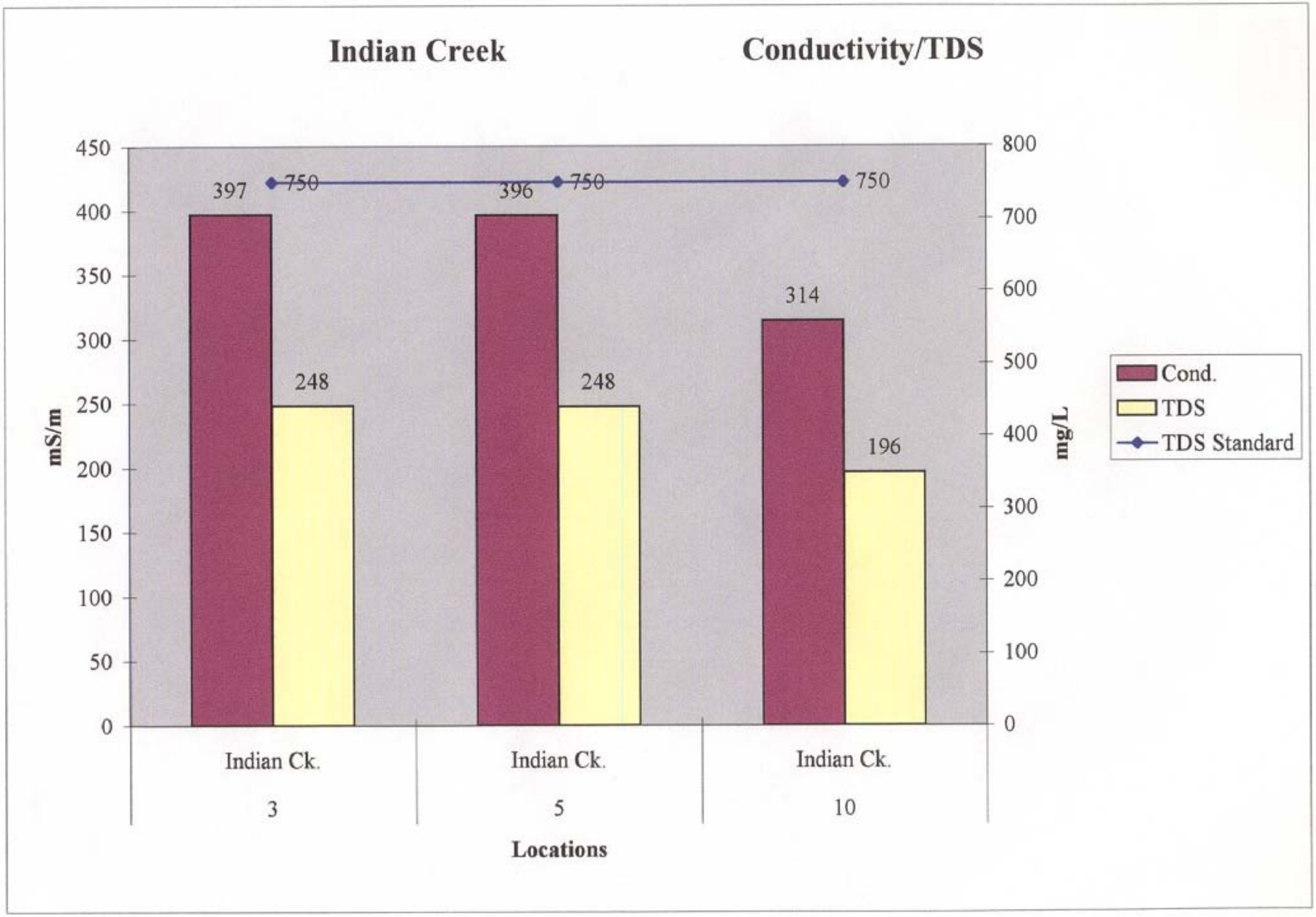
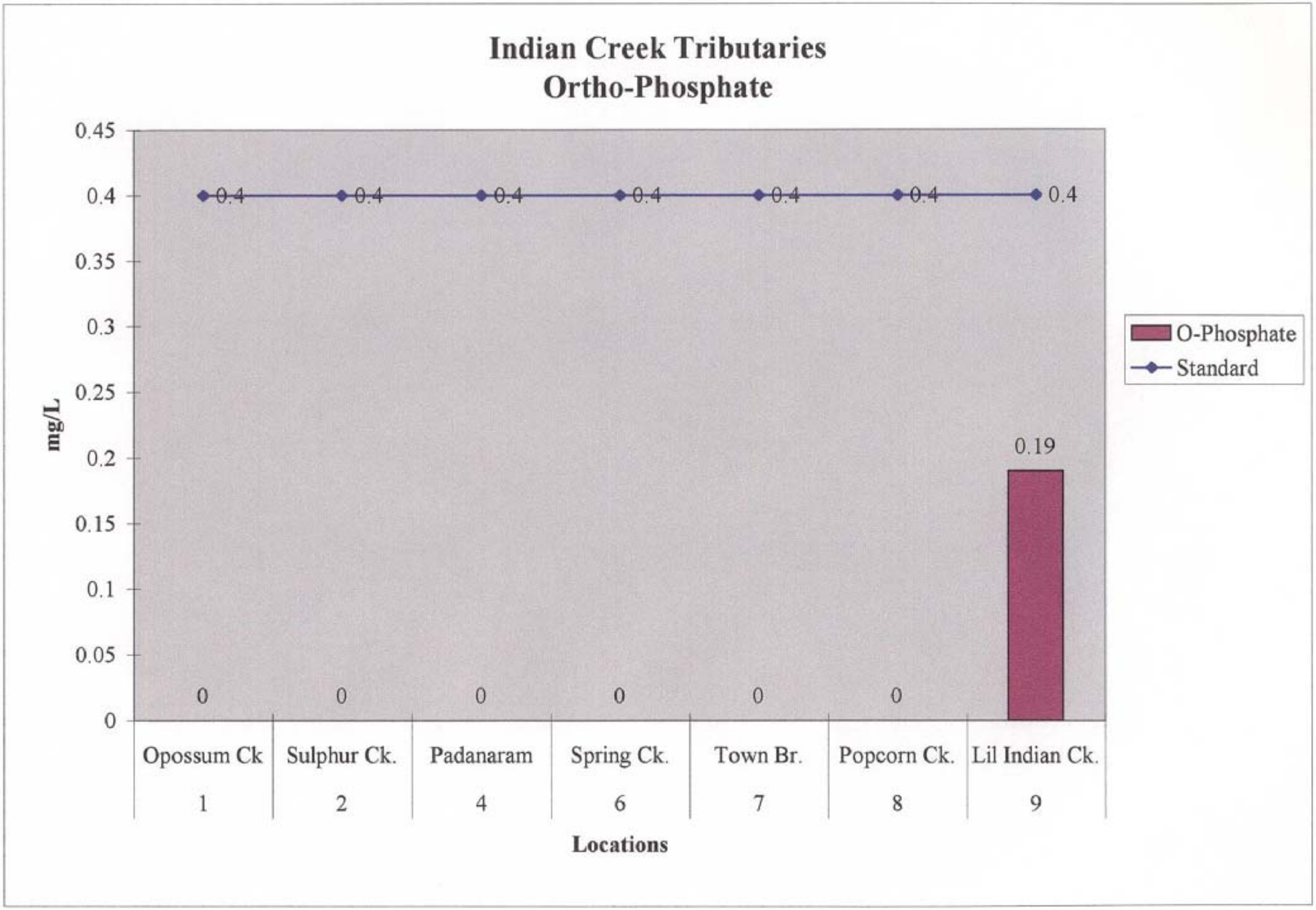

Indian Creek Tributaries Conductivity/TDS
600
500
400
300
200
100
0
mS/m
800
700
600
500
400
300
200
100
0
mg/L
443
277
464
290
314
196
399
249
268
168
555
347
241
151
750
750
750
750
750
750
750
Cond.
TDS
Standard
Opossum Ck
Sulphur Ck.
Padanaram
Spring Ck.
Town Br.
Popcorn Ck.
Lil Indian Ck.
1
2
4
6
7
8
9
Locations

Figure V-15



Indian Creek
Conductivity/TDS
450
400
350
300
250
200
150
100
50
0
mS/m
800
700
600
500
400
300
200
100
0
mg/L
397
396
314
248
248
196
750
750
750
Indian Ck.
3
Indian Ck.
5
Indian Ck.
10
Locations
Cond.
TDS
TDS Standard

Figure V-16



Indian Creek Tributaries
Ortho-Phosphate
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
mg/L
0.4
0.19
O-Phosphate
Standard
Opossum Ck
Sulphur Ck.
Padanaram
Spring Ck.
Town Br.
Popcorn Ck.
Lil Indian Ck.
1
2
4
6
7
8
9
Locations

Figure V-17

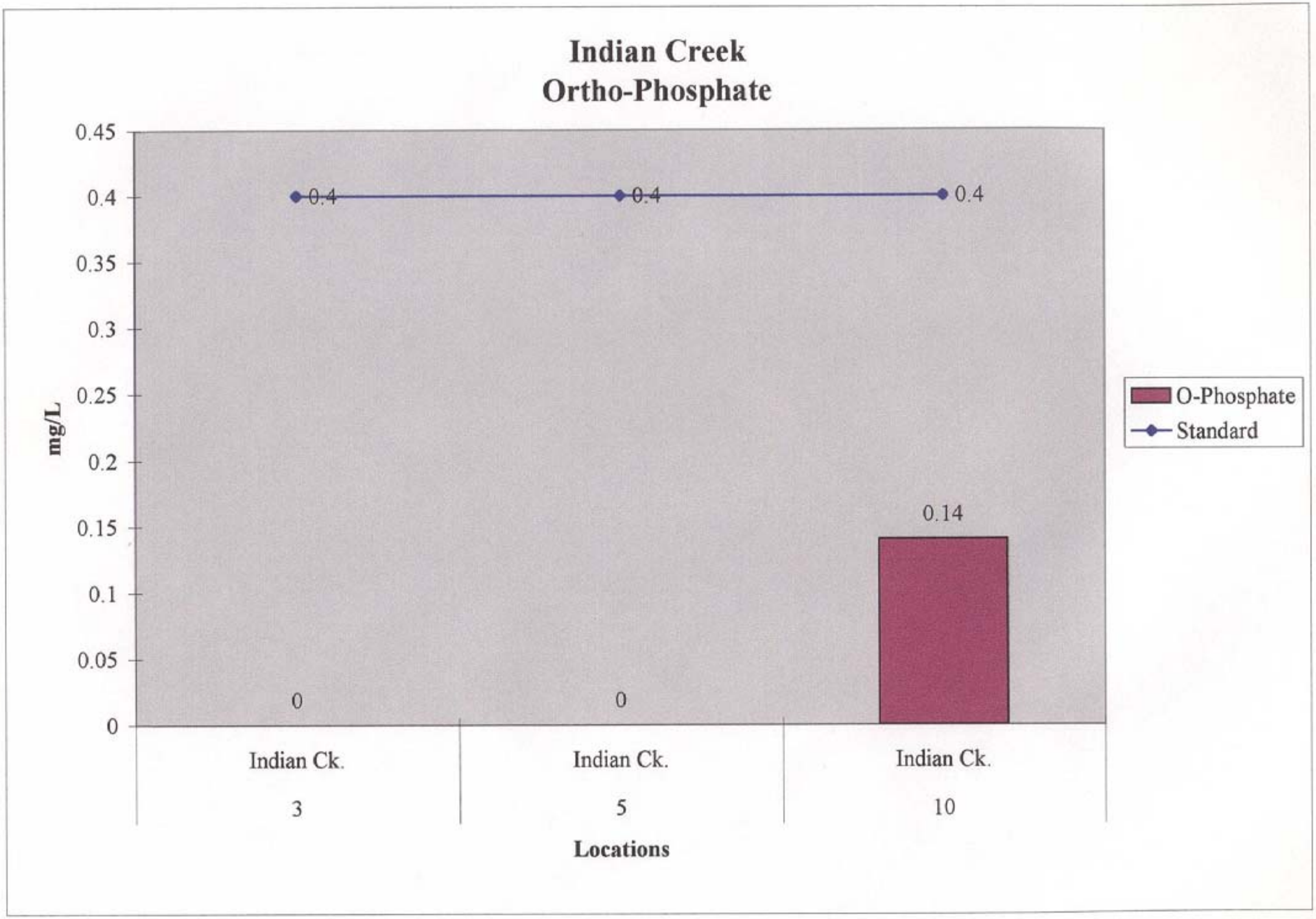
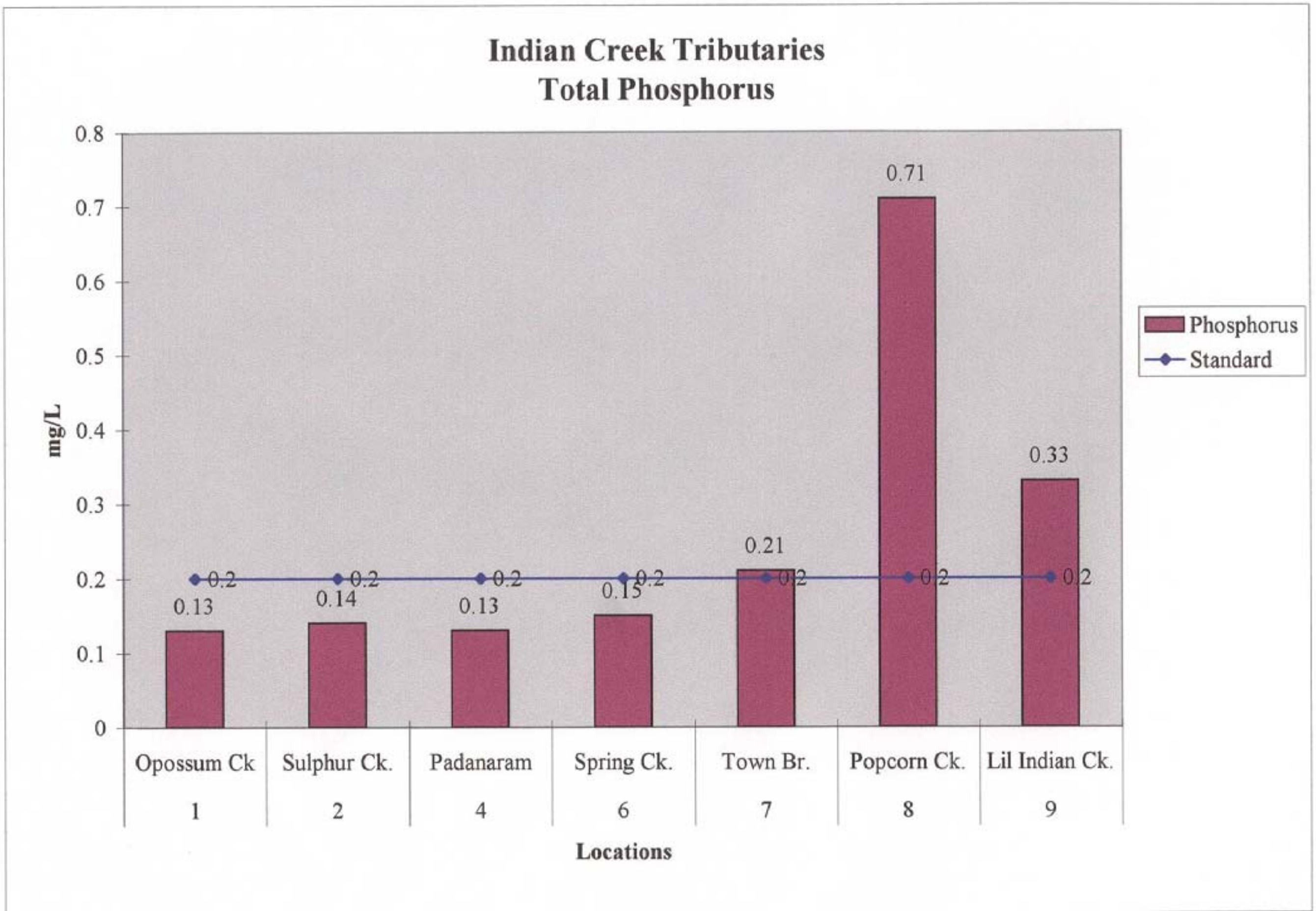
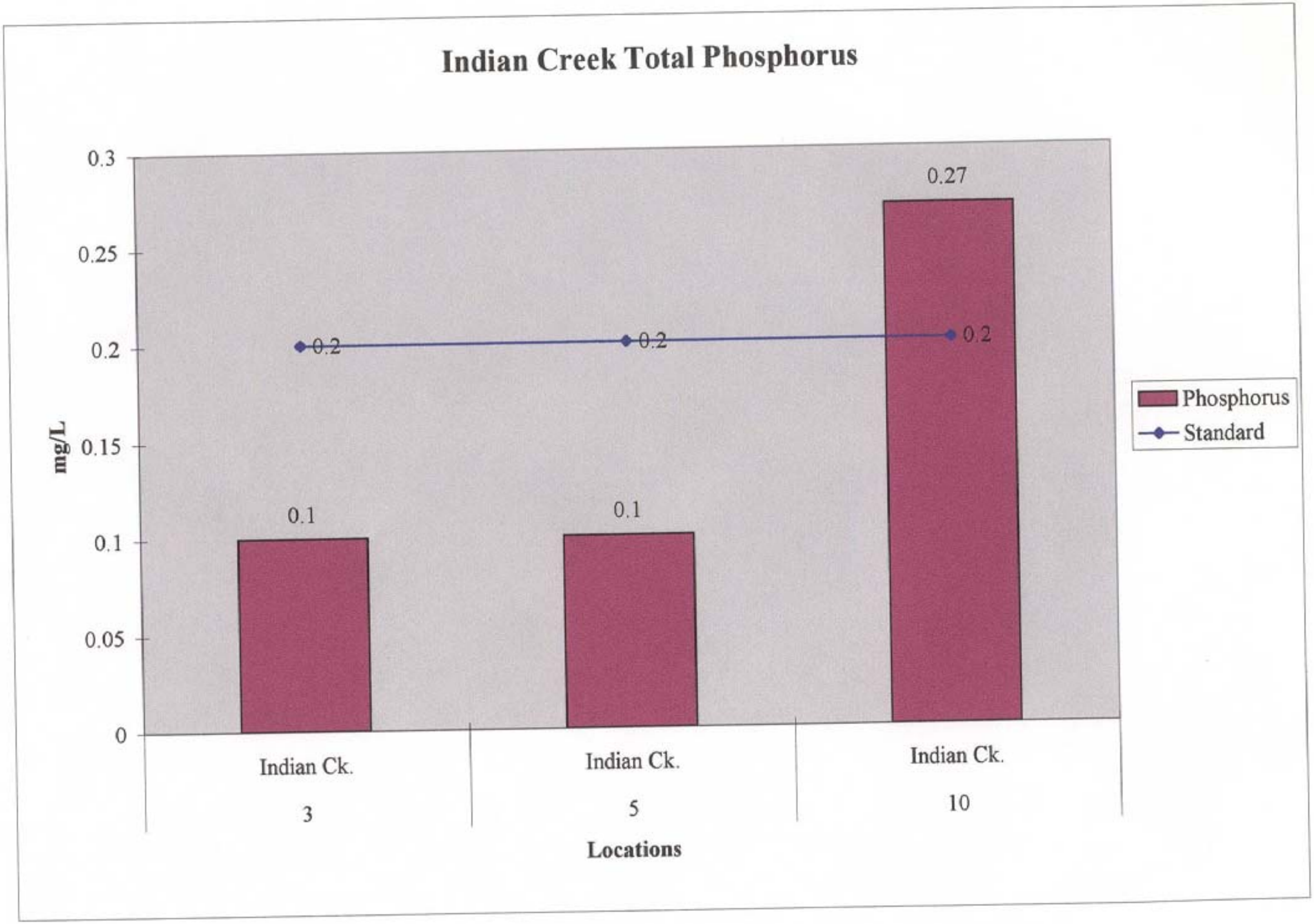

Indian Creek
Ortho-Phosphate
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
mg/L
0.4
0.4
0.4
0.14
0
0
O-Phosphate
Standard
Indian Ck.
3
Indian Ck.
5
Indian Ck.
10
Locations

Figure V-18

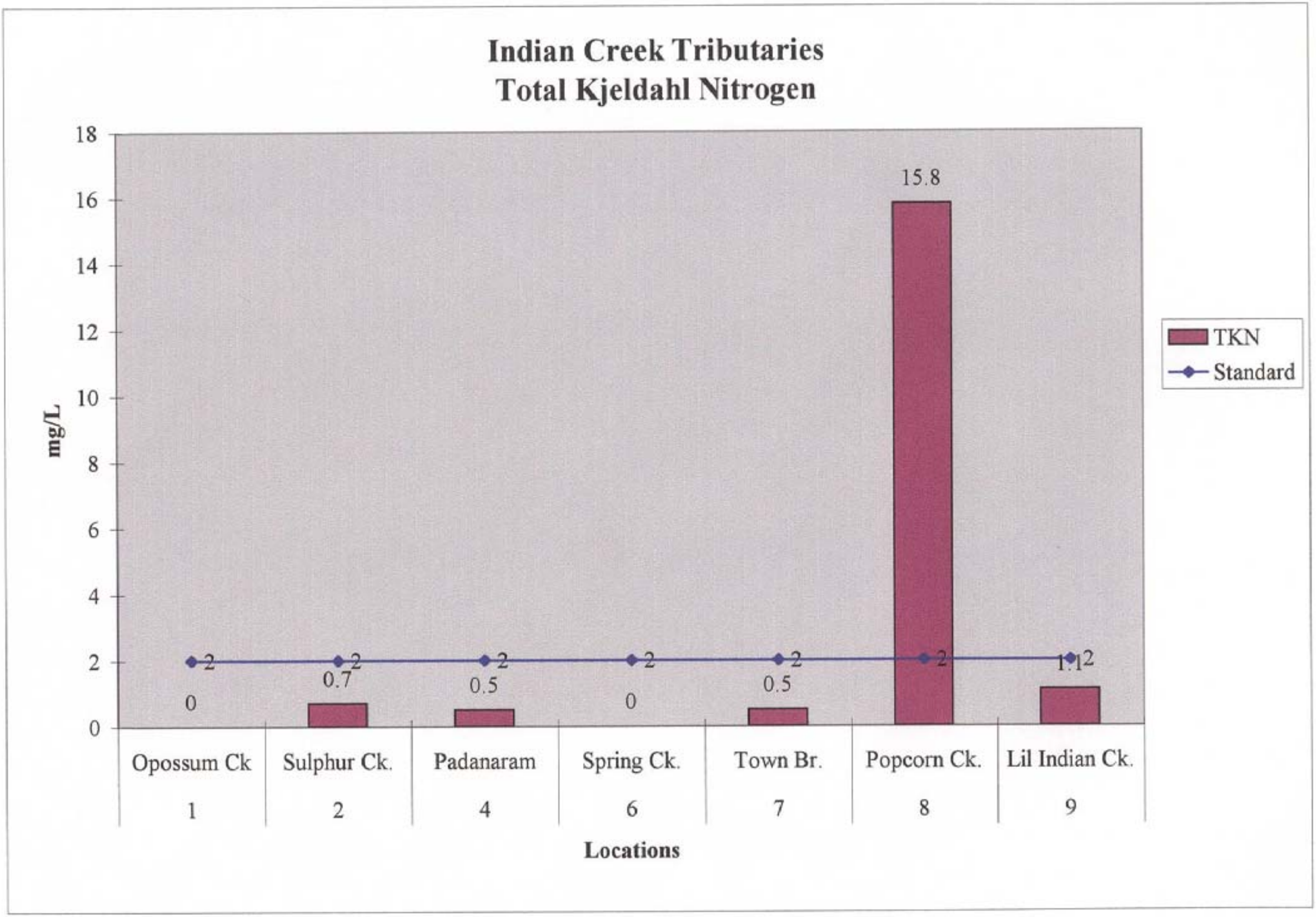


Indian Creek Tributaries
Total Phosphorus
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
mg/L
0.13
0.14
0.13
0.15
0.21
0.71
0.33
0.2
Phosphorus
Standard
Opossum Ck
Sulphur Ck.
Padanaram
Spring Ck.
Town Br.
Popcorn Ck.
Lil Indian Ck.
1
2
4
6
7
8
9
Locations

Figure V-19



Indian Creek Total Phosphorus
0.3
0.25
0.2
0.15
0.1
0.05
0
mg/L
0.1
0.1
0.27
0.2
0.2
0.2
Phosphorus
Standard
Indian Ck.
3
Indian Ck.
5
Indian Ck.
10
Locations


Indian Creek Tributaries
Total Kjeldahl Nitrogen
18
16
14
12
10
8
6
4
2
0
mg/L
15.8
2
0.7
0.5
0
1.1
TKN
Standard
Opossum Ck
Sulphur Ck.
Padanaram
Spring Ck.
Town Br.
Popcorn Ck.
Lil Indian Ck.
1
2
4
6
7
8
9
Locations

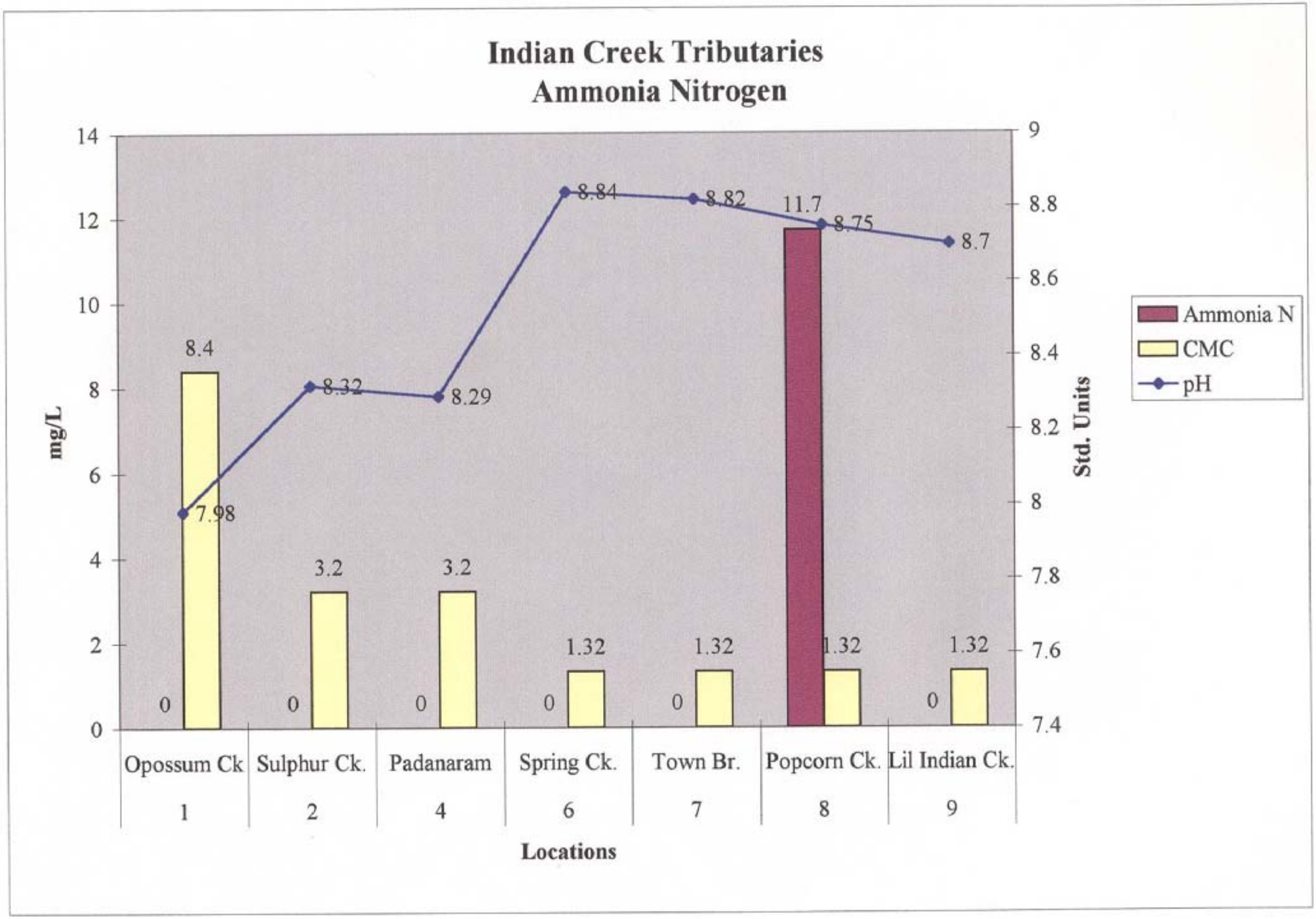
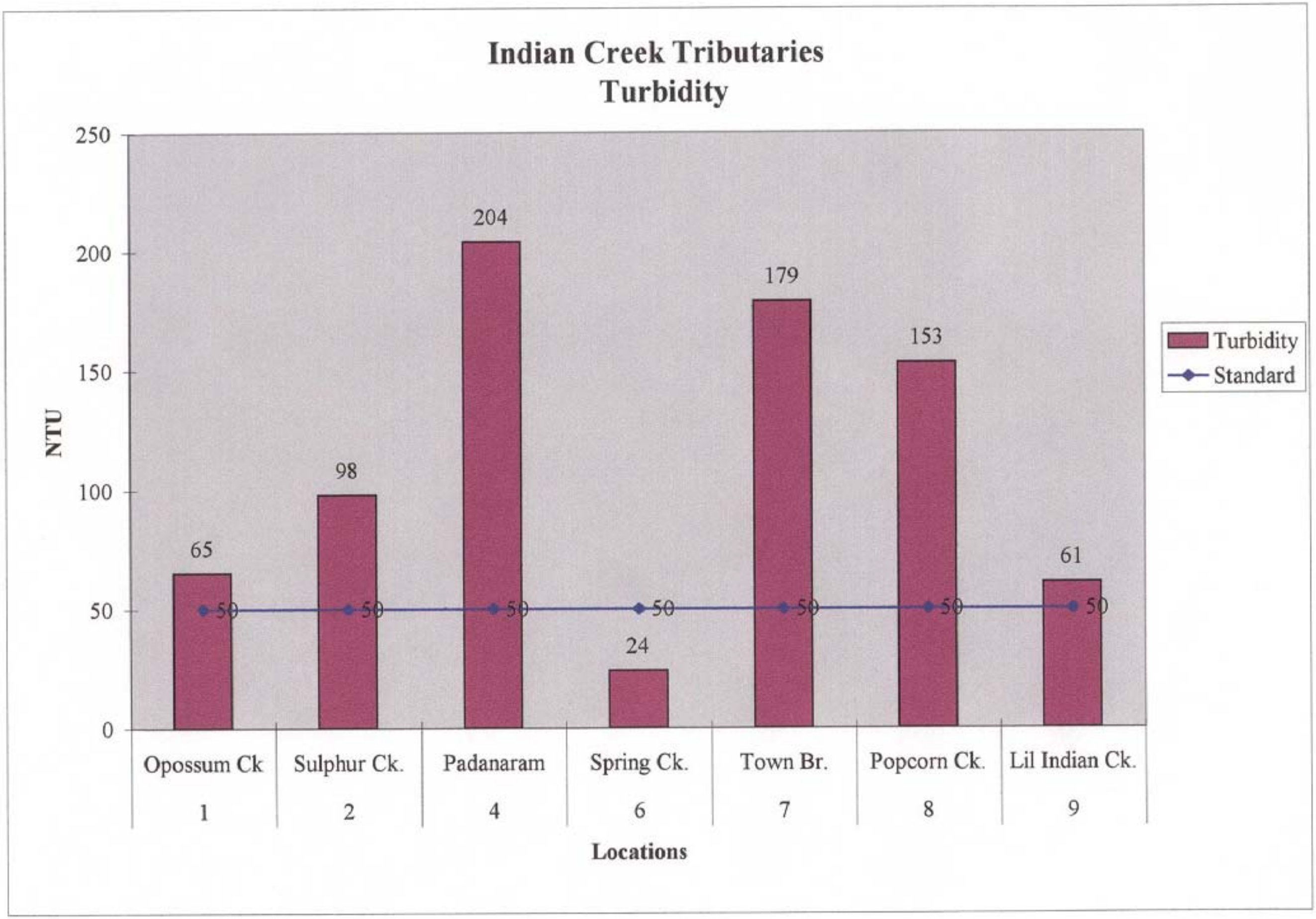
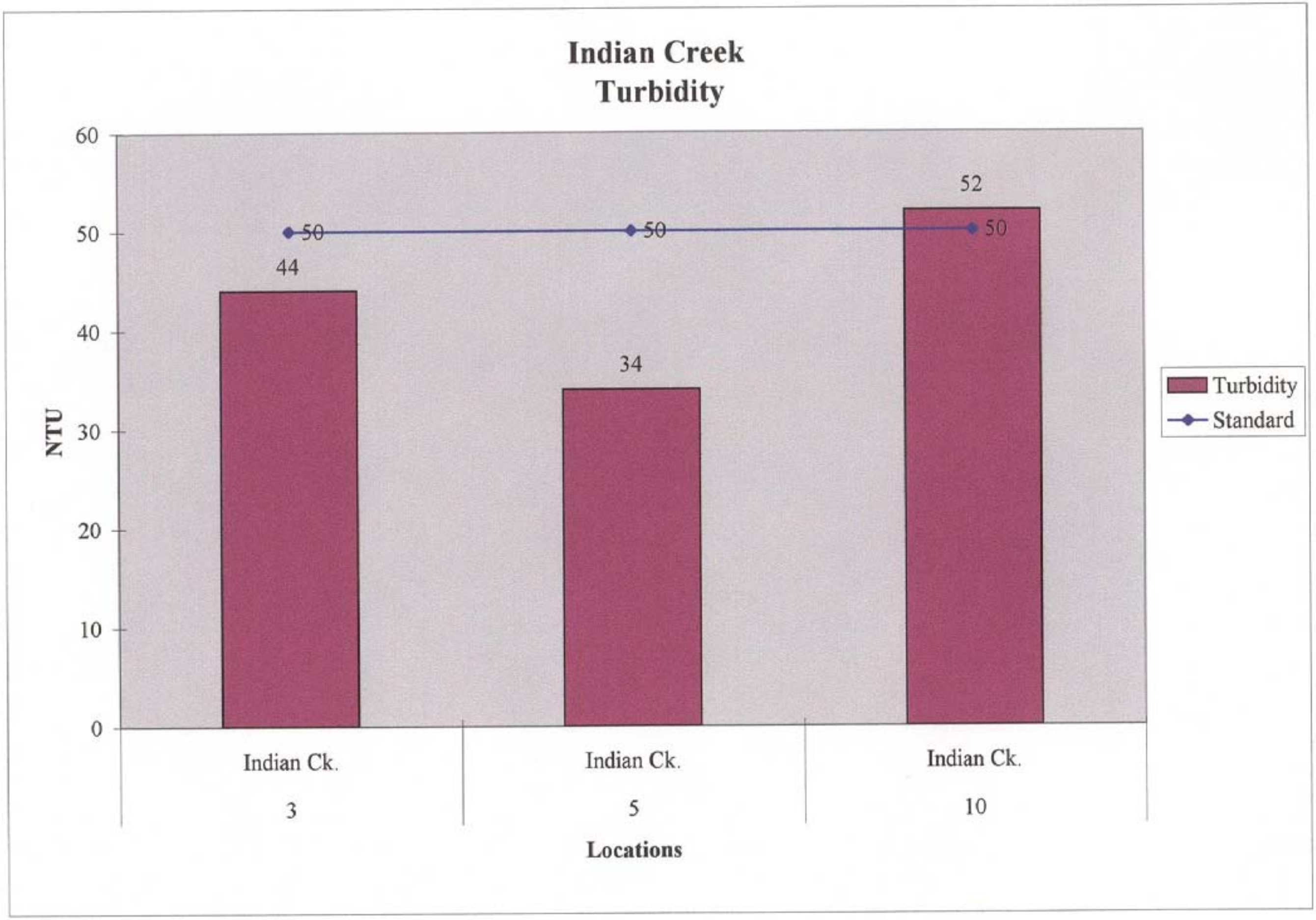

Indian Creek Tributaries
Ammonia Nitrogen
mg/L
Std. Units
Locations
Ammonia N
CMC
pH
8.4
3.2
3.2
1.32
1.32
11.7
1.32
1.32
0
7.98
8.32
8.29
8.84
8.82
8.75
8.7
Opossum Ck
Sulphur Ck.
Padanaram
Spring Ck.
Town Br.
Popcorn Ck.
Lil Indian Ck.
1
2
4
6
7
8
9

Figure V-22



Indian Creek Tributaries
Turbidity
250
200
150
100
50
0
NTU
204
179
153
98
65
61
24
50
Turbidity
Standard
Opossum Ck
Sulphur Ck.
Padanaram
Spring Ck.
Town Br.
Popcorn Ck.
Lil Indian Ck.
1
2
4
6
7
8
9
Locations


Indian Creek
Turbidity
NTU
60
50
40
30
20
10
0
44
34
52
50
50
50
Indian Ck.
3
Indian Ck.
5
Indian Ck.
10
Locations
Turbidity
Standard

The pH, Conductivity, Turbidity, Temperature, and Dissolved Oxygen were measured as field parameters. A Horiba® U-10 Water Quality Checker was used to determine the field parameters. All other parameters were laboratory tested. Samples were placed into appropriate containers with preservatives (if needed) and stored in ice chests until delivered to the laboratory. Disposable field vacuum filtration systems, with 0.45 micron mesh filters, were used to filter samples for dissolved phosphorus testing.

All sampling techniques and laboratory analytical procedures and methods were performed in accordance with *Standard Methods for the Examination of Water and Wastewater, 17th Edition* (APHA, 1989). Figure V-3 summarizes field and laboratory data for sampling location within Indian Creek and the sampled tributaries.

A. Dissolved Oxygen

Dissolved Oxygen (DO) is the measure of the amount of life-sustaining oxygen dissolved in the stream water and, therefore, available to fish, invertebrates, and all other organisms living in the stream. The higher the level of DO, the more variety of life the stream can support. DO then, is arguably the most important parameter of water for aquatic organisms. Most organisms need oxygen to fuel the chemical reactions involved in respiration.

The absence of oxygen is often a sign of severe pollution within the stream. Different species of organisms have different DO requirements. Only a few are able to live in low concentrations such as carp, catfish, and bloodworms. Most sport fish species suffer if DO concentrations fall below a concentration of 3-4 mg/L. Larvae and juvenile fish are more sensitive and require even higher levels. Many fish and other aquatic organisms can recover from short periods of low DO in the water. However, prolonged episodes of depressed DO concentrations of 2 mg/L or less can result in dead waterbodies. Prolonged exposure to low DO conditions can suffocate adult fish or reduce their reproductive survival by suffocating sensitive eggs and larvae. In addition, low DO can starve fish by killing aquatic insect larvae and other prey. Low DO concentrations also favor anaerobic bacteria that produce the noxious gases or foul odors often associated with polluted waterbodies.

Water absorbs oxygen directly from the atmosphere, and from plants as a result of photosynthesis. The ability of water to hold oxygen is influenced by temperature and salinity. Water loses oxygen primarily by respiration of aquatic plants, animals, and microorganisms. Due to their shallow depth, large surface exposure to the atmosphere, and constant motion, streams generally contain abundant DO. However, external loads of oxygen-demanding wastes or excessive plant growth induced by nutrient loading followed by death and decomposition of vegetative matter can deplete oxygen. When organisms die, their tissues will decompose through the process of aerobic respiration, which requires oxygen. This process removes oxygen from the aquatic ecosystem. Therefore, a large influx of organic matter into a stream can greatly decrease the amount of oxygen that is available to organisms, possibly causing periods of die-off. This process, referred to as biochemical oxygen demand, can compound itself as lowered DO levels lead to die-off which further reduces the DO level resulting in a cyclic effect.

Any loading of organic material from a watershed to a stream results in an oxygen demand. Excess loads of organic material may arise from a variety of land use practices, combined with storm events, erosion, and washout. Some agricultural activities, particularly large-scale animal operations and improper manure application, can result in significant BOD loads- reducing DO concentrations. Land-disturbing activities of silviculture and construction can result in high organic loads through the erosion of organic topsoil. Runoff from residential areas often times is loaded with high concentrations of organic materials derived from a variety of sources.

B. pH

Alkalinity, acidity, and buffering capacity are important characteristics of water that effect its suitability for aquatic life and influence chemical reactions. The acidic or alkaline nature of water is commonly quantified by the negative logarithm of the hydrogen ion concentration, or pH. A pH value of 7 represents a neutral condition; a pH of less than 5 indicates moderately acidic conditions; a pH greater than 9 indicates moderately alkaline conditions.

Many biological processes, such as reproduction, cannot function in acidic or alkaline waters. In particular, aquatic organisms may suffer an osmotic imbalance under sustained exposure to low pH waters. Rapid fluctuations in pH also can stress aquatic organisms. Finally, acidic conditions also can aggravate toxic contamination problems through increased solubility, leading to the release of toxic chemicals stored in stream sediments. Stream water in the Indian Creek watershed tends to be somewhat alkaline.

C. Conductivity

Conductivity is a numerical expression of the ability of an aqueous solution to carry an electric current. This ability depends on the presence of ions and their concentration dissolved in the solution. Conductivity in a sense then is an indirect measure of the total dissolved solids in a stream. Conductivity measurement in mS/m can generally be multiplied by 0.625 to obtain an equivalent dissolved solids concentration in mg/L. These dissolved solids include salts, some organic materials, and a wide range of other things from nutrients to toxic substances.

Both high and low concentrations of dissolved solids can negatively impact a stream; however, dissolved ions of nutrients are important for growth of organisms. Dissolved ions can include calcium, bicarbonate, nitrogen, phosphorus, iron, and sulfate. High concentrations can have a laxative effect and result in poor tasting water. In addition, dissolved solids include things that are both good and bad for living organisms. Surface water quality standards have been set and dissolved solids are not to exceed 750 mg/L in all waters of the State. The equivalent conductivity value is 1200 mS/m.

D. Turbidity

Turbidity is a measure of the dispersion of light in a column of water due to various things suspended in the water. These suspended materials include soil colloids and other non-living things, as well as algae and other small forms of life.

The criteria for turbidity in surface waters is <50 NTU for the protection and propagation of warm water fish and other organisms. The effects of too much turbidity includes a decline in the diversity of aquatic organisms. This is due in part to temperature increases with higher turbidity, which results in lowered dissolved oxygen. Other effects include decreased photosynthesis due to reduced light penetration. The suspended matter also can clog fish gills causing die-off.

E. Temperature

Water temperature (measured in °C) is a crucial factor in a stream ecosystem for a number of reasons. First, dissolved oxygen solubility decreases with increasing water temperature, therefore the stress imposed by oxygen-demanding waste increases with higher temperature. Second, temperature governs many biochemical and physiological processes in cold-blooded aquatic organisms, and increased temperatures can increase metabolic and reproductive rates throughout the food chain. Third, many aquatic species can tolerate only a limited range of temperatures, and shifting the maximum and minimum temperatures within a stream can have profound effects on species composition. Finally, temperature also affects many abiotic chemical processes, such as reaeration rate, sorption or organic chemicals to particulate matter, and volatilization rates. Temperature increase can lead to increased stress from toxic compounds, for which the dissolved fraction is usually the most bioactive fraction.

The criteria for temperature in surface waters for the protection and propagation of cold water fish and other organisms is <20 °C.

F. Nitrate Nitrogen

Nitrate concentration is a measure of the oxidized form of nitrogen in the stream water, which is the basic building block for proteins. Nitrates are directly useable by living organisms, and are an essential macronutrient in an aquatic ecosystem.

A healthy aquatic ecosystem should not have too many or too few nitrates. The usual circumstance is too many nitrates, which can result in too much algae and fast aquatic plant growth. Eventually this results in an abundance of decaying organic material, which depletes dissolved oxygen levels. The end result is reduced diversity and a lower quality of life for aquatic organisms.

Too few nitrates in solution results in an inadequate nutrient supply for aquatic organisms, which also results in lower diversity and reduced quality of aquatic life. Less decay results in less ammonia, which can lead to a breakdown in the nitrogen cycle. The surface water quality standard set by the State is a maximum of 10 mg/L.

G. Nitrite Nitrogen

Nitrite nitrogen is an intermediate form of nitrogen in the cycle. In the most basic concept, the cycle begins when fish eat and excrete ammonia. The ammonia is toxic to fish and must be removed or changed to a harmless form. Bacteria consume the ammonia and excrete nitrite, which is also toxic to fish. Another type of bacteria consumes the nitrite and excrete nitrate. Nitrate, as previously discussed, is non-toxic to fish in small concentrations and is used by plants and algae as fertilizer. Completing the cycle, the fish eat the plants and again excrete ammonia.

Since nitrite is an intermediate form or step in the nitrogen cycle, typical measurements are in the range of 0.1 to 0.2 mg/L or below detection. In all of the sample locations of the Indian Creek watershed, nitrite levels were below detection.

H. Ammonia Nitrogen

Ammonia is a measure of the reduced form of nitrogen and is a basic building block for proteins. Ammonia is the form of nitrogen produced by nitrogen-fixing bacteria and is the form in which nitrogen commonly appears in polluted streams. It is directly useable by living organisms, and constitutes an essential macronutrient in aquatic ecosystems.

Ammonia toxicity to fish is linked to water temperature and pH. Surface water quality standards are in place defining criteria maximum concentrations (CMC or acute criterion) and criteria continuous concentrations (CCC or chronic criterion). In addition, there are differences in species acute sensitivity such that different CMC values were derived for waters where salmonids (trout, salmon) are present and where salmonids are not present as salmonids tend to be more sensitive to ammonia.

The trend is that CMC level standards decrease as pH increases; however, CMC level standards increase slightly as temperature increases. Figure V-21 shows the results of ammonia monitoring in tributaries of Indian Creek. Samples collected from Indian Creek itself were below detection levels when tested for ammonia. The graph sets CMC standards relative to pH. All samples collected had ammonia levels below the detection level with the exception of Popcorn Creek, which had a level of 11.7 mg/L with a CMC set at 1.32 mg/L.

I. Total Kjeldahl Nitrogen

There are several laboratory tests used to measure the different forms of nitrogen. In order to determine organic and ammonia nitrogen, the test commonly used is Total Kjeldahl Nitrogen (TKN). Since TKN measures both ammonia nitrogen and organic nitrogen, it is standard procedure to also measure the ammonia nitrogen as discussed above. This in turn can be used to determine the fraction of the TKN that is associated with the organic nitrogen.

TKN levels in samples collected from Indian Creek were all below detectable levels. Typical levels in natural waters range from 0.2 to 2.0 mg/L therefore the standard was set at 2.0 mg/L for TKN. Tributaries to Indian Creek that were sampled were all well below the standard with the exception of Popcorn Creek which has a TKN level of 15.8 mg/L.

J. Phosphorus

Phosphorus is the most important factor in the cultural eutrophication of streams throughout the world. Both phosphorus and nitrogen are essential nutrients for the plants and animals that make up the aquatic food web. Since phosphorus is the nutrient in shortest supply in most fresh waters, even a modest increase in phosphorus can, under the right conditions, set off a whole chain of undesirable evens in a stream, including accelerated plant growth, algae blooms, low dissolved oxygen, and the death of certain fish, invertebrates, and other aquatic animals.

Phosphorus in aquatic systems occurs as organic phosphate and inorganic phosphate. Organic phosphate consists of a phosphate molecule associated with a carbon-based molecule, as in plant or animal tissue. Phosphate that is not associated with organic material is inorganic, the form required by plants. Animals can utilize either organic or inorganic phosphate. Both organic and inorganic phosphate can either be dissolved in the stream water or suspended in the water column.

There are a large number of sources and a variety of routes that phosphorus can take making it difficult to monitor or correct problems with phosphorus over-enrichment. Two basic references for phosphorus analysis methods include a total of twelve different tests for phosphorus. Total phosphorus is the form of greatest interest since total phosphorus includes potentially available as well as immediately available phosphorus. Carlson's Trophic State Index for lakes categorizes lakes with the poorest water quality as being hypereutrophic and that system uses total phosphorus as an indicator. Hypereutrophic lakes generally have a total phosphorus concentration of >0.1 mg/L (100 ppb) which is the value set as the standard for the Indian Creek watershed monitoring. Essentially all sample locations within Indian Creek and all sampled tributaries had phosphorus levels equal to or exceeding this standard.

K. O-Phosphate

Orthophosphate or O-Phosphate is a measure of the amount of phosphorus actually available to organisms inhabiting the stream at a point in time. The term orthophosphate is a chemistry-based term that refers to the phosphate molecule alone. "Soluble reactive phosphate (SRP)" is a corresponding method-based term that describes what is actually measured when performing the test for orthophosphate. The O-Phosphate or SRP then represents the soluble inorganic forms of phosphorus that are readily available to plants. It does not include inorganic condensed phosphate forms, such as those found in detergents.

Aquatic plants require nitrogen and phosphorus in different amounts. Typically the range of nitrogen to phosphorus required is from 5 to 20 (N:P 5-20) such that phosphorus is the limiting nutrient. When the ratio deviates from this range, plants cannot use the nutrient present in excess amounts. The other nutrient, in this case phosphorus, is then considered to be the limiting nutrient on plant growth. In streams experiencing excessive nutrient loading, the typical approach is to control loading of the limiting nutrient at levels that prevent nuisance conditions.

Laboratory analysis for O-Phosphate was quantified to the 0.1 mg/L concentration level even though concentrations below that level may be sufficient to allow nuisance conditions to develop. Since concentrations below 0.1 mg/L were not quantified, the standard for this project is set at 0.1 mg/L and this standard was exceeded at the Little Indian Creek sampling location and at location #10 in Indian Creek which is located near the head of the stream.

L. TSS (Total Suspended Solids)

Total Suspended Solids is a measure of the solid materials in the stream water that are capable of settling out on the stream bottom when stream velocities are sufficiently low. It includes both organic (plants, organisms) and inorganic (soil) material that is suspended in the water. In streams it is also a measure of erosion.

Suspended material decreases water clarity and settles to the bottom, where it contributes to sediment accumulation. Concentrations of 80 mg/L have been shown to reduce benthic (bottom dwelling) populations of aquatic organisms in lakes. That concentration has been set as a standard for the sampling and analysis conducted for the Indian Creek watershed project. Figure V-4 shows that TSS levels for all locations sampled were below the 80 mg/L concentration.

2. Biological Community Quality/Stream & Riparian Habitat Quality

In Fall 1998, Indiana University Southeast visited Indian Creek to assess the habitat and macroinvertebrates at ten stations. Three of these stations were located on Indian Creek proper, and seven on the tributaries. The results of the study were forwarded to Donan Engineering for submittal to the Indiana Department of Natural Resources.

A. Methods

The 10 stations were at the following locations: (1) Opossum Creek, (2) Sulphur Creek, (3) Indian Creek Downstream, (4) Tributary near Padanaram Commune, (5) Indian Creek Midstream, (6) Spring Creek, (7) Town Branch, (8) Popcorn Creek, (9) Little Indian Creek, and (10) Indian Creek Upstream (Figure V-2).

The methodologies chosen for assessing the biological quality of the above ten sites were published by the Environmental Protection Agency in 1989 in the *Rapid Bioassessment Protocols for Use in Streams and Rivers; Benthic Macroinvertebrates and Fish.* These protocols have been updated, and are now available on the Internet. We used some of the new delineation aspects of the updated materials as an aid in understanding impairment at the stations.

As part of this study, we also developed the QHEI (Qualitative Habitat Evaluation Index) used by the Indiana Department of Natural Resources and others. The QHEI gives an estimate of the suitability of a stream segment to meet warmwater habitat requirements for aquatic organisms. A recorded QHEI of 60 or above on a 100 point scale usually means that the stream segment is suitable for a warmwater habitat without use impairment.

The rapid bioassessment protocols described in this report are best used for detecting aquatic life impairments and assessing their relative severity. Once impairment is detected, it is often necessary to undertake specific studies to identify the causative agents and to develop mitigation procedures (p. 24 of above manual). When mitigation efforts are undertaken, the same procedures can be used to document *environmental recovery.* Thus, these methodologies can be very useful monitoring tools as attempts are made to improve the water quality in Indian Creek and its tributaries.

The bioassessment technique results presented in this report focus on the evaluation of habitat and benthic macroinvertebrate community parameters. Incidental fish catch was accomplished using a seine. Typical water quality parameters were measured using a test kit. The methods and parameters used in each protocol are presented below.

1. Habitat Assessment

The Habitat Assessment Matrix supports the macroinvertebrate biosurvey analysis and is weighted to emphasize the most biologically significant parameters. Using this analysis, all stations are rated. These ratings are then totaled and compared to a reference point that is the very best attainable situation to provide a final habitat percentage ranking.

Habitat parameters are separated into three categories--primary, secondary, and tertiary (p. 5-4 of above manual). The primary parameters are those that characterize the substrate instream habitats that have the greatest influence on community structure. These include (1) bottom substrate and available cover, (2) embeddedness, and (3) flow. Secondary parameters involve an analysis of channel morphology including (1) channel alteration, (2) bottom scouring and deposition, and (3) pool to riffle ratio. Tertiary parameters are designed to measure the riparian and bank structure. Those items assessed include (1) bank stability, (2) bank vegetation, and (3) streamside cover.

The actual habitat assessment involves rating the nine parameters as excellent, good, fair, or poor. A field sheet serves as a guide in this process (Figure 5.2.1 of Rapid Bioassessment Protocols).

The total score obtained for each station is then compared to a high quality reference station. The ratio expressed as a percentage provides a measure for each station. The station is then classified on the basis of its similarity to expected high quality stream conditions. In our analysis, we used an upper control limit of 88% to separate *comparable to a high quality reference* from those habitats that could be considered as *supporting of a variety of aquatic life.* We used a value of 75% to separate *supporting from partially supporting or marginal* habitats

(p. 5-4 of Rapid Bioassessment Protocols). To separate *partially supporting from non-supporting* or poor habitats, we used a value of 58%.

2. Macroinvertebrate Assessment

For the macroinvertebrate analysis, we used a Rapid Bioassessment Protocol III technique (p. 6-16 of Rapid Bioassessment Protocols). This protocol focuses on the invertebrates in the riffle/run habitat, one of the most productive in a stream ecosystem. With our analysis, we obtained three traveling-kick net method samples in the riffles at each station. These samples, known as TKN, were taken with a triangular kick-net with a small mesh. The net is placed on the substrate and is moved upstream for 10 feet while the area in front of the net is agitated for a width of 1 foot directly in front of the net (Standard Operating Procedures Manual, Kentucky Department for Environmental Protection, Division of Water). Samples taken using TKN's and a sorted qualitative sample were preserved in 40% isopropanol and taken to the laboratory where they were sorted, identified to the family taxonomic level and counted. A standard reference sample was catalogued for submission to the reference collection at Purdue University.

Following counting, the numbers were placed on taxonomic sheets so that the metric analyses described below could be calculated.

Taxa Richness

This metric measures the total number of families present. Generally, as habitat diversity, habitat suitability, and water quality increase, the numbers of families will increase (p. 6-13 of Rapid Bioassessment Protocols).

Family Biotic Index

For this analysis, each taxonomic group is assigned a tolerance value from 0 to 10 (p. 6-13 of Rapid Bioassessment Protocols). Taxa with low pollution tolerance rate very low on this scale while pollution tolerant organisms are in the high range. Thus, the computed values increase as water quality decreases. This index is designed to detect organic pollution.

Ratio of Scraper and Filtering Collector Functional Feeding Groups

This metric focuses on the community food base (p. 6-13 of Rapid Bioassessment Protocols). Scrapers are present in numbers when the rocks are covered with diatoms and other attached algae. They tend to decrease when filamentous algae and aquatic mosses increase. The algae and mosses provide good attachment sites for filtering collectors. Of course, excessive nutrient input and organic enrichment provide the fertilizer for an overabundance of algae.

Ratio of EPT Taxa (Ephemeroptera, Plecoptera, and Tricoptera) and Chironomidae Abundances

The EPT to Chironomid ratio is an indication of community balance. Mayflies (Ephemeroptera), Stoneflies (Plecoptera) and Caddisflies (Tricoptera) are organisms often associated with high quality habitats and excellent water quality (p. 6-14 of Rapid Bioassessment Protocols). Very high numbers of midge larvae (Chironomidae) relative to the more sensitive EPT taxa may indicate environmental stress.

Percent Contribution of Dominant Family

This metric uses the dominant taxon as an indication of community balance at the family level (p. 6-14 of Rapid Bioassessment Protocols). A community dominated by relatively few families would indicate environmental stress.

EPT Index

Scientists have determined that the EPT Index normally increases with increasing water quality (p. 6-14 of Rapid Bioassessment Protocols). The EPT summarizes the taxa richness within the insect groups that are considered pollution sensitive.

Community Loss Index

The index measures the loss of benthic species between a reference station and the station of comparison (p. 6-15 of Rapid Bioassessment Protocols). Values increase as the degree of dissimilarity increases.

Shredders (CPOM Sample)

Shredder macroinvertebrates are those that utilize coarse particulate organic matter (CPOM). Shredders are known to be a particularly good indicator of toxic effects since toxicants are adsorbed by the CPOM. Some toxicants such as herbicides and insecticides often are already on the CPOM when they enter the water (p. 6-15 of Rapid Bioassessment Protocols).

After values were tallied for each metric, they were compared with those values obtained for a pristine reference location. By expressing the comparability as a percentage of the reference location, we were able to categorize each station as nonimpaired (comparable to best situation expected in this area), slightly impaired (community structure less than expected with tolerant forms increasing), or moderately impaired with fewer species present and reduction in the EPT taxa.

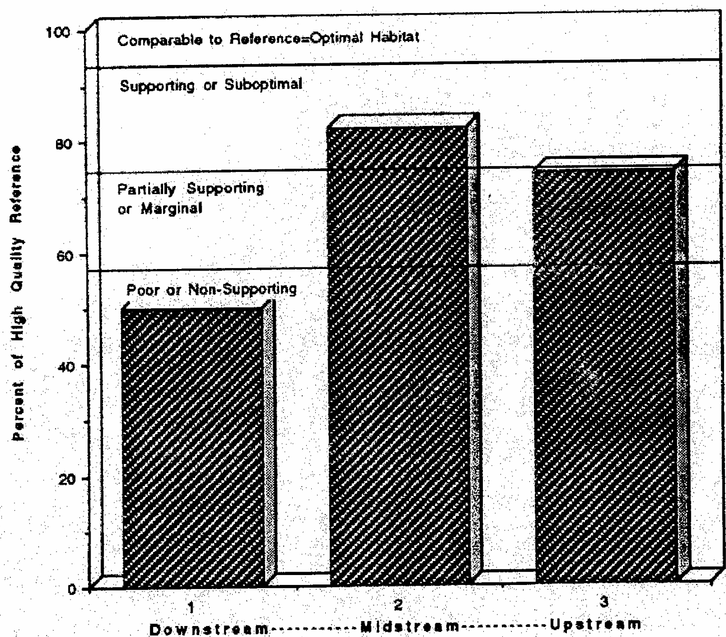
B. Results

Tabular and graphical presentations of the results of the bioassessment protocols for the habitat and macroinvertebrate analysis are given in Figures V-25 - V-30 and Table V-2. Each individual graphical summary is discussed below. The site photographs, QHEI sheets, Habitat Bioassessment sheets, and the macroinvertebrate data sheets are attached in appendices.

1. Habitat Assessment

In Figure V-25, the Stations on Indian Creek proper are listed along the horizontal line while the percent comparison to a pristine, unaltered high quality reference stream is listed along the vertical scale. We set a comparison percentage of 88% as a dividing line between comparable to reference optimal habitat and supporting. We set another dividing line separating supporting from partially supporting or suboptimal. Finally, we used less than 58% to delineate those areas that are non-supporting or poor.

Figure V-25
Habitat Comparisons for Indian Creek at Three Locations



September 16, 1998

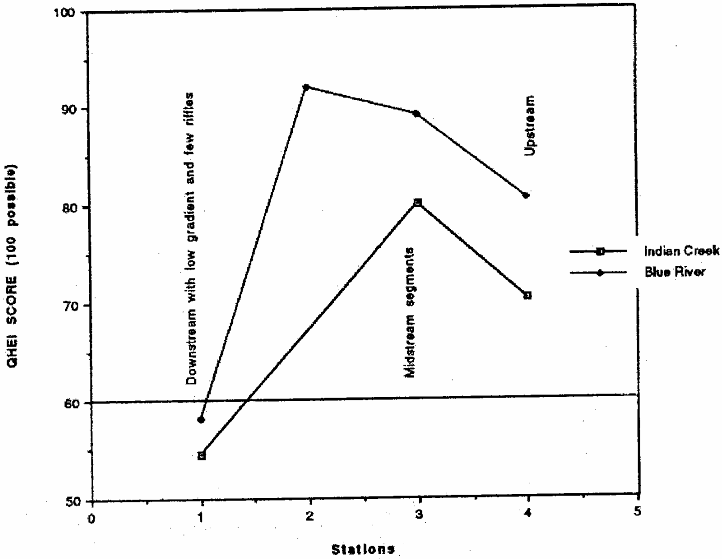
The habitats in the Indian Creek watershed did not compare well with a pristine, high quality reference site with a variety of habitats. The site farthest downstream (Station 3) had the opportunity to be one of the best sites along the stream. The area, however, has been impacted in the riparian zone. The disruption of the understory vegetation has been quite high, and frequent flooding retards proper development. The stream had substantial logs and debris creating jams that trap silt and leaves, thus reducing flow. At the time of our visit, oxygen values were reduced to critical levels, and no shiners or smaller fish were observed swimming in the water. Seine hauls and conversations with locals verified the lack of fish in the area.

Silt embeddedness, instream detritus, and muck with high oxygen demand were judged to be additional detrimental qualities. Water velocity types were reduced to slow deep and slow shallow.

Since impairment was noted at Station 3, we used a portion of the new EPA protocols available on the Internet to further delineate the site. The protocol chosen is divided into Physicochemical and Biological components. In the water quality area, the limiting factor was dissolved oxygen. The causative factors were judged to be lack of rainfall and upstream agriculture and probable logging activities. The lack of rainfall, high temperatures, and oxygen demand of the silt, muck, and leaf detritus worked in concert to produce the low oxygen levels. Local residents indicate that silviculture upstream is responsible for the current demise of this area.

This portion of the stream is reminiscent of the Blue River of southern Indiana where the high pool from the Blue River backs into and floods the lower area of the stream. To verify this observation, we consulted a publication entitled, *Fisheries Survey of Blue River in Crawford, Harrison and Washington Counties* published in 1993 by the Fisheries Section of the Indiana Department of Natural Resources. We also consulted our own in-house data on the Blue River that we prepared for The Nature Conservancy of Indiana. When these data are graphed, the pattern is very similar (Figure V-26). The habitat QHEI's in the Blue River increase as the variety of habitats and flow regimes become available as one proceeds downstream. The QHEI then dives into an unacceptable level at RM 2 near the Ohio River.

Figure V-26
Comparison of QHEI scores for Indian Creek and the Blue River of Southern Indiana



A similar situation occurs on Indian Creek, but the QHEI values are markedly lower than in the Blue River. These lower values are a reflection of the habitat alteration and other problems in the stream.

When compared with a high quality reference stream, the results can be placed into an additional perspective (Figure V-27). The two streams appear similar, but with midstream values in the Blue River at about 90% of reference, the Blue River is considered comparable to reference while Indian Creek falls into the supporting range.

We then evaluated the tributaries of Indian Creek using both the QHEI and % Comparison results. These data are depicted graphically in Figure V-28. Using both methodologies, we delineated problems with Opossum Creek and Town Branch. The remainder of the sites rated as suboptimal or marginal using the % comparison method. Using the QHEI method, we found that the tributaries were able to function as warm water streams. These were not optimal values, however, since 100 is a perfect score using the QHEI scale. By comparison, the average QHEI for 9 reaches of the Blue River was about 83 while the average % comparison with a high quality reference was 80%.

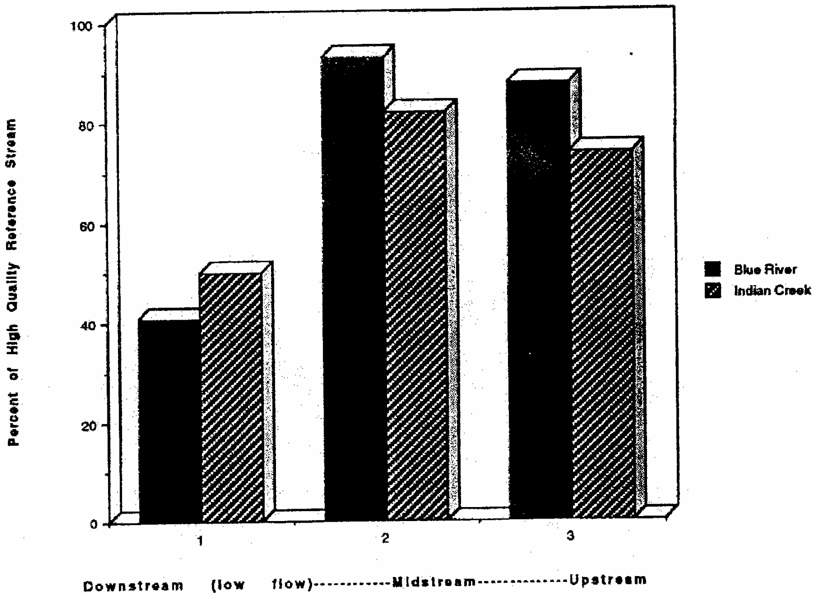
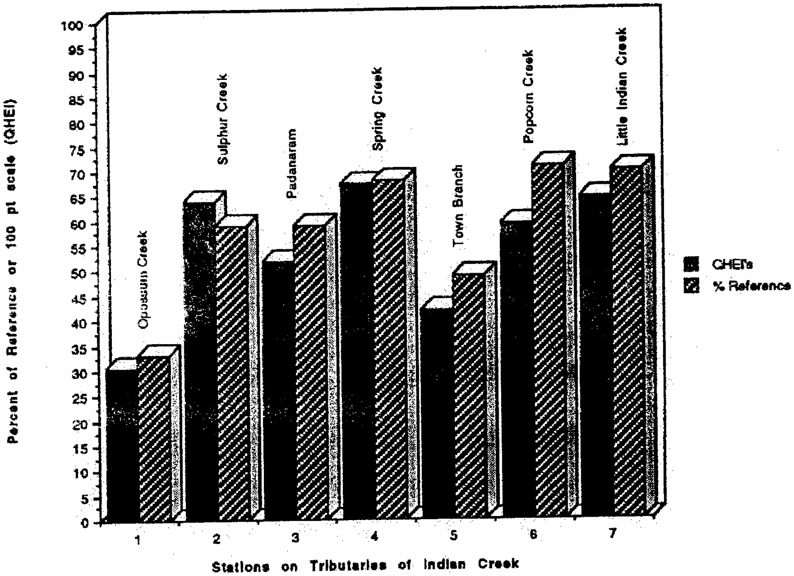


Figure V-27
Comparison of Stations on Indian Creek and Blue River

Figure V-28
Habitat Comparisons for Tributaries
of Indian Creek Using QHEI Scores and Percent
Comparison with a Pristine Resource



2. Macroinvertebrate Bioassessment

The results of the macroinvertebrate bioassessment are given in Table V-2 and Figures V-29 and V-30. In Table V-2, the results from the macroinvertebrate analysis are presented with values for a high quality reference. The bioassessment numbers were then summed to produce a total score and an average score for each site. These scores indicated that all sites were either slightly or moderately impaired. Moderately impaired stations included both downstream sites on Indian Creek and the Opossum Creek and Popcorn Creek tributaries. These tabular results indicated that the two best sites in terms of invertebrate quality were in the highest reaches of the watershed--Stations 9 (Little Indian Creek) and Station 10 (Indian Creek). This trend from moderately impaired eventually to slightly impaired suggests that water quality increases as one proceeds upstream.

TABLE V-2. Summary of Macroinvertebrate Metrics for Ten Stations on Indian Creek. 1998.

Station No.	1	2	3	4	5	6	7	8	9	10	Reference
Taxa Richness Families	16	17	8	16	18	16	19	15	15	16	8-21
Metric Score TR	4	6	0	4	6	4	6	4	4	4	Score=6
Family Biotic Index (FBI)	7.28	5.98	4.87	6.04	6.54	4.44	4.20	8.23	4.73	4.53	4.59
Metric Score FBI	2	4	6	4	4	6	6	0	6	6	6
EPT/ Chironomidae	1.6	1.0	1.81	14	0.70	5.01	3.63	0.31	4.66	77	9.286
Metric Score	0	0	0	6	0	2	0	0	2	6	6
CPOM Community Shredders/Total	0	0	0	0	0	0.084	0	0.0009	0	0.01	
Metric Score	0	0	0	0	0						6
EPT index	4	3	4	4	5	5	7	5	5	5	8-24
Metric Score EPT	0	0	0	0	0	0	4	0	0	0	6
% Contribution Dominant Taxon	65%	30	39.7	31.8	38.3	30.2	25.4	68.7	20.2	23.1	34%
Metric Score	2	6	4	6	4	6	6	2	6	6	3
Community Loss											
Metric Score	4	4	2	4	4	4	4	4	4	4	6
Ratio of Scrapers to Filterers	0.14	1.41	3.90	2.53	0.38	0.24	0.41	0.04	1.56	0.81	1.5
Metric Score	0	6	6	6	2	2	2	0	6	6	6
Total Score	12	26	18	26	20	26	26	10	28	32	45
Average	1.5	3.25	2.25	3.25	2.5	3.25	3.25	1.25	3.5	4	5.62

Analysis: Station 1 --Poor--26% of Reference. Moderately Impaired
Analysis: Station 2--Good--58% of Reference. Slightly Impaired
Analysis: Station 3--Fair--40% of Reference. Moderately Impaired
Analysis: Station 4--Good--58% of Reference. Slightly Impaired
Analysis: Station 5--Fair--44% of Reference. Moderately Impaired
Analysis: Station 6--Good--58% of Reference. Slightly Impaired
Analysis: Station 7--Good--58% of Reference. Slightly Impaired.
Analysis: Station 8--Poor--22% of Reference. Moderately Impaired
Analysis: Station 9--Good--62% of Reference. Slightly Impaired.
Analysis: Station 10--Excellent--71 % of Reference. Slightly Impaired.

The designations, Poor, Fair, Good, and Excellent, were derived from the KY Division of Water, 1993.
Taxa Richness=Site TR/RefTR x 1 00 >80%=6; 60-80=4; 40-60=2; <40=0. In similar subsamples, an outstanding resource water in Kentucky (Laurel Fork) had 26 families of macroinvertebrates.
FBI=Site FBI/Ref FBI x 100 >85%=6; 70-85=4; 50-70=2; <50%=0
EPT/Chironomidae=Site Ratio/Ref Ratio x 100 >75%=6; 50-75=4; 50-70=2; <50=O
Shredders/Total=>50%=6; 35-50%=4; 20-35%=2; <20%=O
EPT Index=Site/Reference x 100 >90%=6; 80-90%=4; 70-80=2; <70=O. In 100-300 organism subsamples, 14-21 EPT taxa were identified in an outstanding resource water.
% Contribution of Dominant Family or Taxon 0-35%=6; 35-50%=4; 50-75%=2; >75%=0
Station 1=Chironomidae, Station 2=Asellidae, Station 3=Heptageniidae, Station 4=Pleurocercidae, Station 5=Chironomidae, Station 6=Hydropsychidae, Station 7=lsonychiidae, Station 8=Chironomidae, Station 9=Hydropsychidae, Station 10=Elmidae.
Scrapers/Filterers=Ratio of Site/ Ref Ratio x 100 >50%=6; 35-50=4: 20-35=2; <20%=O
Community Loss. Comparing Stations with macroinvertebrate fauna expected in high quality stream.

We then compared in Figure V-30 the results from Indian Creek with those from the Blue River of southern Indiana. In this figure, downstream, midstream and upstream stations are listed on the horizontal axis, and the percent comparison to a pristine reference is listed on the vertical axis. We set an upper control limit of 79% to separate nonimpaired from slightly impaired, and a lower control limit of 54% to separate slightly impaired from moderately impaired. The graphical information is illuminating in that midstream stations on the Blue River are nonimpaired (or in some cases slightly impaired) while the station on Indian Creek was moderately impaired. The upstream stations for Indian Creek and Blue River were very similar. The trend in the Blue River is for the macroinvertebrate structure to continually improve as the stream approaches the Ohio River. The trend in Indian Creek appears strikingly opposite to recorded information from the Blue River. Although we have minimal instream stations for Indian Creek, the trend seems to support decreasing quality as we move downstream.

Figure V-29
Results of Rapid Bioassessment for Indian Creek and Tributaries. Protocol II

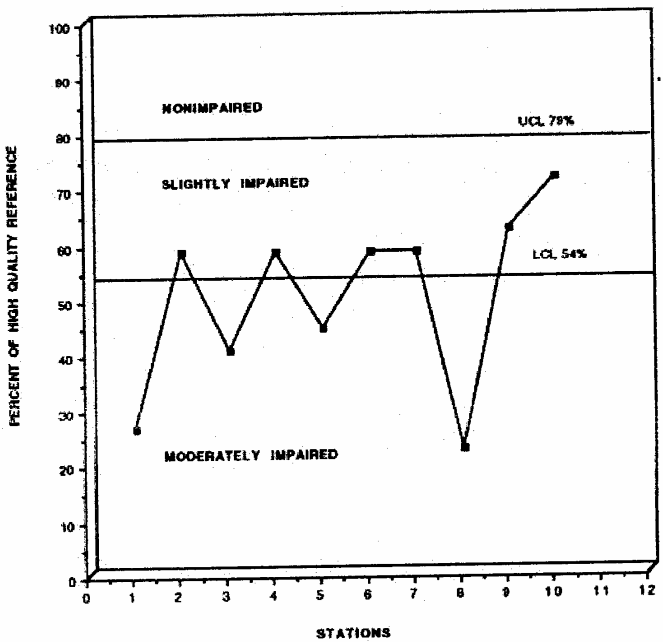
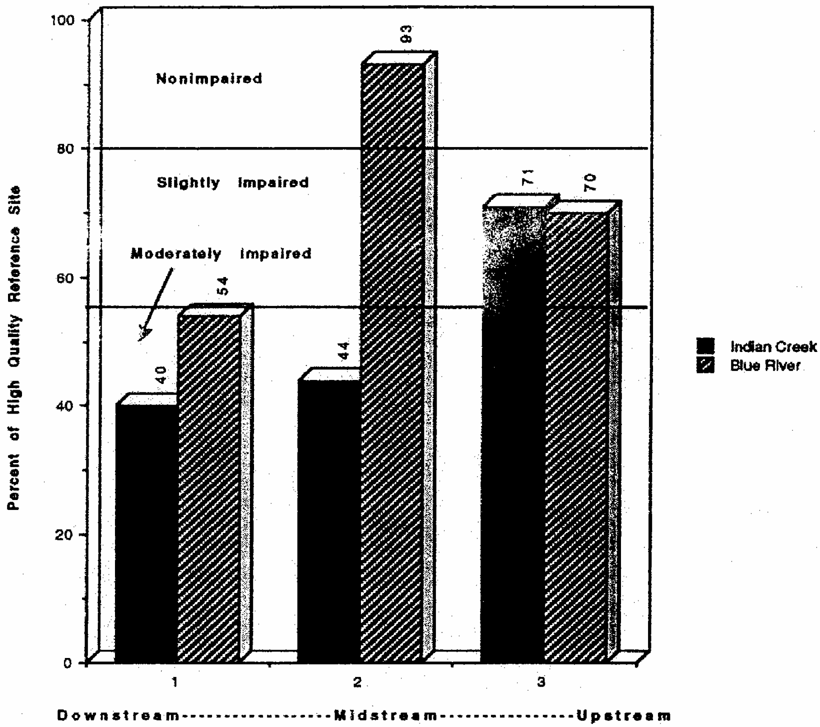


Figure V-30
Comparison of Blue River and Indian Creek
in Three Watershed Areas



3. Individual Macroinvertebrate Metrics

To further analyze these trends, the individual metric data in Table V-2 were analyzed and interpreted. In addition, we evaluated the ecological characteristics of individual families that were numerically dominant (autecology).

Taxa Richness

The Taxa Richness at all sites except Station 3 was substantial, but not in the range expected for a warmwater stream of this type with a variety of available habitats. The taxa missing were primarily intolerant families of mayflies, stoneflies, and caddisflies.

The groups comprise the Ephemeroptera, Plecoptera, and Tricoptera families in the EPT index considered next.

EPT Taxa

In a nonimpaired stream, we would expect to find between 8 and 24 families of Ephemeroptera, Plecoptera and Tricoptera. In our case, we had only about half of the lowest expected number (8). Of these EPT taxa, only one family of stoneflies was found. Of the remaining mayfly and caddisfly larvae identified, most are known to demonstrate a moderate tolerance to pollution and siltation. From the results of this metric, we conclude that pollution sensitive EPT taxa have been eliminated from the Indian Creek watershed.

Stoneflies most often are found in clean, highly oxygenated streams. Organic enrichment and siltation can limit their occurrence. The susceptibility of stonefly larvae to sediments causes them to be one of the first organisms to disappear when a stream is impacted. In Indian Creek, only one family known as common stoneflies *(Plecoptera perlidae)* was found at four upstream stations. Common stoneflies are normally found in riffles. As young, they feed on plant material. As they age, they switch and become active predators. These stoneflies are somewhat tolerant to pollutants.

EPT/Chironomidae

The total number of specimens from the EPT group was compared with the numbers of chironomid (midge larvae) specimens. Chironomid numbers were high leading to low ratios at all sites except Stations 4 and 10. Chironomids are known for their pollution tolerance, thus, their elevation numbers suggest environmental stress at most stations on Indian Creek.

Autecology of Dominant Families

Some instruction regarding water quality in Indian Creek is provided by study of the autecology (relationship with the environment) of the dominant taxa at the various sites.

Chironomid midge larvae were dominant at Stations 1 and 8 where large clumps of algae were noted. They also became abundant in the mainstream habitat at Station 5. Midge larvae are known to thrive in dense algal mats where they remove dead and decaying material. In addition, they often become very abundant in areas receiving sewage, and thus are good indicators of degraded water quality.

The caddisflies known as common netspinners, Hydropsychidae, were the dominant taxon at Stations 6 and 9. These larvae are, during some part of their life cycle, collectors of suspended food. They are among the most abundant caddisflies in the Midwest, are considered to be one of the most tolerant species, and are resistant to sediment pollution. We have found large numbers of this family in many streams in Indiana and Kentucky.

Heptageniid or flatheaded mayflies were the dominant family at Station 3. These tolerant mayflies typically are found on the undersides of the rocks common in riffle areas. They normally graze on algae and detritus associated with the substrate. Interestingly, the brushlegged mayfly, *Isonychia,* was the dominant species at Station 7 and was present at other upstream stations. These low tolerance mayflies filter fine particles from the water. We have found these species in eastern Kentucky near extant cattle operations.

Freshwater snails were locally abundant as we moved downstream and at Station 4 were the dominant organism. Snails are able to rasp and scrape algae from the rocks and become locally very abundant in the late summer and fall in some of our Indiana streams.

Although not a dominant family by number, several large dobsonfly larvae were noted at some of the stations. The dobsonfly larvae, known locally as Hellgrammites, are large voracious carnivores that feed extensively on caddisfly larvae. These larvae have the ability to withstand some siltation and may not be as pollution intolerant as originally thought.

Family Biotic Index

The Family Biotic Index (FBI), with higher numbes indicating higher levels of organic pollution, provided values in the moderate range for five of the stations. The remainder--Stations 1, 2, 4, 5 and 8--had elevated numbers. The very high values for Opossum Creek (Station 1) and Popcorn Creek (Station 8) approach those recorded for a degraded stream in an urban situation.

The macroinvertebrate list was then scanned to determine if any extremely tolerant organisms were present at the stations. We found snails, amphipods, isopods, and bloodworms (Chironomidae) all have high tolerance values.

Community Loss

We compared our stations with what might be expected for a high quality stream. Each station had some community loss. A pristine wooded reference without development or habitat alteration would be expected to have over 20 families while our best site had only 19. The missing taxa were intolerant stonefly, mayfly and caddisfly families. Also missing were several species of Odonata (damselflies and dragonflies).

Shredders (Coarse Particulate Organic Matter Community, CPOM)

As noted in the methods section, these organisms are the ones that shred and use leaves and other materials. We found only minimal numbers of this functional group in Indian Creek. A problem could be that we did the study before leaves would have been processed. We need to continue the study in the late winter and spring when processing of this component is occurring to fully evaluate the abundance of the shredding community. We did tear open leaf packs, where available, and found that shredders had not infiltrated leaf packs.

Ratio of Scrapers to Filterers

The scraper functional group was present at nearly all stations. There was, however, a difference in the types of scraping organisms. Tolerant snails were the predominant scrapers downstream in the watershed. As we moved upstream, macroinvertebrate beetle larvae like water pennies and riffle beetles were the predominant scraper organisms.

Freshwater Mussels and Asiatic Clams

Even though relict freshwater mussel shells were noted in Opossum Creek, we did not find any living mussels in the stream during this survey. Asiatic clam shells, however, were common in the downstream portion of the watershed. A raccoon midden containing a large number of these shells was noted at Station 5. The lack of a mussel fauna is another indication of degraded water quality for this stream.

Historic Fish Analysis

A review of Gerking's historic fish analysis for Indiana did not provide historic information for this watershed.

C. Conclusions

1. Habitat Bioassessment

The habitat quality analysis indicated the watershed has most of the ingredients necessary to support a variety of aquatic life, but none of the sites were comparable to a pristine, high quality reference stream with a forested watershed. The downgrading of the stream centered around several identifiable factors. First, the combination of extensive row crop agriculture and existing cattle operations has led to organic enrichment and siltation. In some cattle operations, the problem can be addressed simply by excluding the cattle from the environment. In corn and soybean operations, more conservation tillage and adequate riparian buffers may serve to improve water quality.

Improving downstream Indian Creek may be more problematic. Presumably, the heavy silt load and channel modifications have led to the degradation of the banks and the existing fallen trees in the stream channel. In addition, hypoxia (lack of oxygen) may have decimated the fish population and the organisms living in the sediments. This downstream section may be a conduit for sediment generated upstream and may not necessarily be from adjacent areas.

The logs and debris serve to reduce the already slow movement of water down the channel. Cursory examination suggests that the riffle to pool ratio in the area is already quite low. The study of channel clogging debris might be necessary to determine if mitigation procedures can and should be developed. It seems plausible that the removal of obstructions might improve conditions in the lower end of the stream.

2. Macroinvertebrate Bioassessment

Indian Creek and its tributaries did not fare well in the macroinvertebrate bioassessment. Water quality decreased as we proceeded downstream. The stream has lost most of its intolerant macroinvertebrates, and the presence of chironomids at most stations suggests some organic contamination. A Family Biotic Index also detected severe organic enrichment at two sites. The analysis revealed that taxa richness is reduced to mainly moderately tolerant organisms. When our data were compared with results from a pristine reference site, missing taxa were almost all species of intolerant stoneflies, mayflies and caddisflies that are susceptible to elevated silt and organic enrichment.

3. Freshwater Mussels

An existing freshwater mussel population was not present in this watershed. The absence of mussels is another indication of degraded water quality compared to other regional streams.

VI. POLLUTANT SOURCES

All activities on earth, both natural and those initiated by man, produce some type of by-product from that activity. Under normal circumstances these by-products, some known as pollutants, are re-cycled back into the environment. Natural environmental processes have the ability to correct an imbalance if given sufficient time. However, if a persistent over-load of a pollutant is allowed to continue, the environment cannot keep up and clean itself.

In the simplest of terms, a pollutant is defined as a substance that tends to elevate the "natural" background of that substance once it gets into the environment. Often times, there may not be significant or any amount of the substance in the environment to start with.

Of greatest concern to this study, are the pollutants that get into Indian Creek from both rural and urban sources or activities. The main six types of pollutants that reduce the quality of surface water include:

- Sediment- associated with wind and water erosion of soils
- Nutrients- from fertilizers, animal wastes, sewage treatment plants.
- Animal wastes- Fecal coliform from livestock and septic systems
- Pesticides- Herbicides, insecticides, fungicides, etc.
- Salt- Mainly from applied road salt
- Toxics- Manufactured and refined products like oil, paints, anti-freeze, etc.

Pollution entering waterways can be divided into two broad types: point and non-point source pollution. Point sources are generally more conspicuous than non-point sources. As the term implies, the source is traceable to a single point of discharge- generally a pipe of other conveyance or outfall structure. Point sources are often regulated by state or federal statutes and permits (i.e. NPDES permits). Examples include municipal wastewater treatment plants; industrial process water discharges, failed or improperly operated septic systems, and feedlots. Non-point sources, on the other hand, are more scattered and far less discernible. Generally, non-point sources of pollution originate from the surface of a watershed- usually associated with man's activity. Examples include amendments applied to agricultural land, erosion from agricultural and construction activities, and exposed industrial activities.

1. Point Sources

Point sources arise from a definite or distinct source such as a wastewater treatment plant, industrial facility, or similar source those discharges through a pipe, conduit, or similar outlet. They are relatively easy to identify by tracing the discharge back to a specific source. Point sources were traditionally considered to be the primary sources of pollution to water bodies. This is no longer true for most lakes and streams. Harder to identify and harder to control nonpoint sources are more likely to be the principal contributors of nutrient and sediment loads.

2. Nonpoint Sources

One definition used for non-point source pollution is pollutants from a source that is not required to have a National Pollutant Discharge Elimination System (NPDES) Permit. NPDES permits are required for cities, industries, storm water runoff from cities over 100,000 population, storm water runoff from certain industries and animal feedlots with more than 1,000 animal units. Everything left over is a non-point pollutant source.

Non-point source pollutants with the potential to significantly impact Indian Creek include sediments, nutrients, animal waste, and pesticides. These and other materials wash off the land and into the stream directly or they are delivered by tributaries throughout the watershed. Lack of adequate vegetation facilitates the loss of these materials particularly on steep slopes and stream banks. However, even well vegetated lands can become non-point sources when water flow is fast enough to create channels. Inadequately treated wastewater from residential septic systems is also considered a significant non-point source of pollution.

An extensive study of non-point sources of pollution in the Great Lakes Basin was performed by the International Reference Group on Great Lakes Pollution from Land Use Activities (Sonzogni et al., 1980). The results of this study found significant differences in land uses and the potential non-point source pollution generated by each. TableVI-1 is reproduced from that study.

Table VI-1. Ranges of Non-point Source Pollutant Loads by Land Use
(kg/ha/year)
(Source: Sonzogni et al., 1980)

Land Use	Suspended Solids	Total Phosphorus	Total Nitrogen	Chloride
Rural				
Cropland	20-5100	0.2-4.6	4.3-31	10-50
Improved Pasture	30-80	0.1-0.5	3.2-14	-
Forest	1-820	0.02-0.67	1-6.3	2-20
Idle	7-820	0.02-0.67	0.5-6.0	20-35
Urban				
Residential	620-2300	0.4-1.3	5-7.3	1050
Commercial	50-830	0.1-0.9	1.9-11	10-150
Industrial	450-1700	0.9-4.1	1.9-14	75-160
Developing urban	27,500	23	63	-

Table VI-2. Ranges of Non-point Source Pollutant Loads by Land Use
(lb/acre/year)
(Source: Sonzogni et al., 1980)

Land Use	Suspended Solids	Total Phosphorus	Total Nitrogen	Chloride
Rural				
Cropland	18-4550	0.18-4.1	3.8-28	9-45
Improved Pasture	27-71	0.1-0.4	2.9-12.5	-
Forest	1-730	0.02-0.6	1-5.6	2-18
Idle	6-730	0.02-0.6	0.4-5.4	18-31
Urban				
Residential	550-2050	0.4-1.2	4.5-6.5	940
Commercial	45-740	0.1-0.8	1.7-9.8	9-135
Industrial	400-1517	0.8-3.7	1.7-12.5	67-143
Developing urban	24,500	20	56	-

The results of this study found significant differences in land uses and the non-point pollution they generate. In rural areas, conventional cropping systems can result in exposed soils being vulnerable to erosion with the potential to have elevated levels of suspended solids. However, the table also shows that disturbances associated with construction activities in the development of urban lands can result in significant suspended solids and nutrient loading of runoff from those areas.

Studies of non-point source pollution tend to focus on identifying and quantifying non-point source loads associated with various land uses. However, landform characteristics can have a greater impact on the extent of non-point source pollution than the land use. These characteristics include soil texture, soil type, surficial geology, slope, and soil chemistry and the characteristic having the single most impact on pollution potential is soil texture. Soil texture is defined as the relative proportions or distribution of particles of sand, silt, and clay. Overall, runoff is more prevalent on fine-grained clay soils than on coarse-grained sandy soils. Clay-sized particles are easily suspended, however they settle very slowly. Consequently, the probability of transport over land in sheet runoff is very high. Furthermore, clay soils generally have more associated pollutants due to a higher adsorption capacity, which compounds the situation.

Table VI-3 gives the runoff coefficients (% of precipitation that runs off the surface as opposed to infiltrating the surface) for various common rural surfaces based on cover, soil types, and slope. Runoff increases as the percent slope and clay content increases (Marsh and Borton, 1976).

Table VI-3. Runoff Coefficients for Various Rural Land Uses (Source: Marsh and Borton, 1976)

Topography & Vegetation	Open Sandy Loam	Clay and Silt Loam	Tight Clay
Woodland			
Flat (0-5% slope)	0.1	0.3	0.4
Rolling (5-10% slope)	0.25	0.35	0.5
Hilly (10-30% slope)	0.3	0.5	0.6
Pasture			
Flat (0-5% slope)	0.1	0.3	0.4
Rolling (5-10% slope)	0.16	0.36	0.55
Hilly (10-30% slope)	0.22	0.42	0.6
Cultivated			
Flat (0-5% slope)	0.3	0.5	0.6
Rolling (5-10% slope)	0.4	0.6	0.7
Hilly (10-30% slope)	0.52	0.72	0.82

It follows then that non-point source pollution and the associated loading to Indian Creek are heavily influenced by land cover and land use. Figure IV-13 presented the distribution of land cover and land use for Indian Creek watershed indicating 35% is crop/pastureland. Figures IV-14 through IV-18 summarize the breakdown of land use and land cover by subwatershed. Spring Creek and Little Indian Creek, with 60% and 57% crop/pastureland respectively, and Popcorn Creek with 37% crop/pastureland, are expected to be more significant sources of non-point source pollution than, for example, Sulphur Creek watershed with 10% crop/pastureland. This observation is based solely on land cover and land use. Beyond that however, landform characteristics also must be considered. In essence, not only is it imperative to examine the trends in land use of the watershed, but also the land form characteristics where those land uses are being applied.

A. Agriculture

The United States has over 330 million acres of agricultural land that produce an abundant supply of low cost, nutritious food and other products. IDNR estimates that 25,000 acres of Indian Creek's 108,000-acre watershed is cropland. Although American agriculture is noted worldwide for its productivity, quality, and efficiency, improperly managed agricultural activities can have a serious affect on water quality. According to the most recent *National Water Quality Inventory* report, agricultural non-point source pollution is the leading source of water quality impacts to the rivers and lakes surveyed. Agricultural non-point source pollution has also been identified as a major contributor to ground water contamination and wetlands degradation.

The primary agricultural non-point source pollutants are nutrients, sediment, animal wastes, salts, and pesticides. Agricultural activities also have the potential to directly impact the habitat of aquatic species through physical disturbances caused by livestock or equipment, or through the management of the water resource.

1. Nutrients

Nitrogen (N) and phosphorus (P) are the two major nutrients from agricultural land that degrade water quality. Nutrients are applied to agricultural land in several different forms and come from various sources, including, commercial fertilizer, manure, municipal and industrial treatment plant sludge or effluent, legumes and crop residues, irrigation water, and atmospheric deposition.

All plants require nutrients for growth. In aquatic environments, nutrient availability usually limits plant growth. N and P generally are present at background or natural levels below 0.3 mg/L N and 0.05 mg/L P. However, when these nutrients are introduced into a stream at higher rates, aquatic plant productivity can increase dramatically. This adds more organic material, which eventually dies and decays. The decaying organic matter produces unpleasant odors and depletes the oxygen supply required by aquatic organisms. Depleted oxygen levels can reduce the quality of fish habitat and encourages the propagation of fish that are adapted to less oxygen.

Highly enriched waters will stimulate algae production, with consequent increased turbidity and color. This results in less sunlight penetration and availability to submerged aquatic vegetation that provides habitat for small fish. The loss of this submerged aquatic vegetation can have a severe impact to the food chain.

2. Sediment

Sediment affects the use of water in many ways. Suspended solids reduce the amount of sunlight available to aquatic plants, cover fish spawning areas and food supplies, clog the filtering capacity of filter feeders, and clog and harm the gills of fish. Turbidity interferes with the feeding habits of fish and chemicals such as pesticides, phosphorus, and ammonium are transported with sediment and in adsorbed state.

Soil eroded and delivered from cropland as sediment usually contains a higher percentage of finer and less dense particles than the parent soil on the cropland. This change in composition of eroded soil is due to the selective nature of the erosion process. Larger particles are more readily detached from the soil surface because they are less cohesive, but they also settle out of suspension more quickly because of their size. Organic matter is not easily detached because of its cohesive nature, but once detached it is easily transported because of low density. Clay particles and organic residues will remain suspended for longer periods and at slower flow velocities than larger more dense particles. This selective erosion process can increase overall pollutant delivery per ton of sediment delivered because small particles have a much greater adsorption capacity than larger particles. As a result, eroding sediments generally contain higher concentrations of P, N, and pesticides than the parent soil from which they were eroded.

3. Animal Wastes

Manure includes the fecal and urinary wastes of livestock and poultry, process water (such as from a milking parlor), and the feed, bedding, litter, and soil with which they become intermixed. Pollutants that are contained in manure and associated bedding materials can be transported by runoff water and process wastewater from confined feeding facilities. These pollutants generally include oxygen-demanding substances, N, P, other nutrients, organic solids, salts, undesirable organisms, and sediments.

Dissolved oxygen depletion brought on by oxygen-demanding substances and decaying organic materials delivered to surface waters can result in extensive fish kills which has a compounding effect by adding even more organic material for decay in a stream.

In addition, animal diseases can be transmitted to humans through contact with animal feces. Runoff from fields receiving manure will contain extremely high numbers of bacteria if the manure has not been incorporated into the soil or the bacteria have not been subject to lethal stress. The method, timing, and rate of manure applications are significant factors in determining the likelihood that water quality contamination will result. Manure is generally more likely to be transported in runoff when applied to the soil surface than when incorporated into the soil. Spreading manure on frozen ground or snow can result in high concentrations of nutrients being transported from the field during rainfall or snowmelt, especially when the snowmelt or rainfall events occur soon after spreading.

Within the Indian Creek watershed, the majority of manure applied is in the form of solid manure with bedding which is surface applied. Manure applied to idle cropland can be incorporated into the soil by discing or other primary tillage. The farmer applying manure to pasture or hayland must rely on timing and apply at an appropriate rate to better utilize this resource and reduce the impacts to surface water. Typically, application rates of manure for crop production that are based on N, exceed plant requirements for P and K. The soil generally has the capacity to adsorb P leached from manure applied on land if infiltration occurs. Nitrates, however, are easily leached through the soil into ground water and both phosphorus and potassium can be transported by eroded soil.

4. Salts

Salts are a product of the natural weathering process of soil and geologic material. They are present in varying degrees in all soils and in fresh water and ground water. In soils that have poor subsurface drainage, high salt concentrations are created within the root zone where most water extraction occurs.

High salt concentrations in streams can harm freshwater aquatic plants just as excess soil salinity damages agricultural crops. Salts become concentrated in the soil through a process referred to as the "concentrating effect". That is, as soil water is consumed by plants or lost to the atmosphere by evaporation, the salts remain. This process especially becomes significant in irrigation systems where irrigation return flow carries a salt load that increases as it is circulated through an irrigation system. Large-scale irrigation systems are not utilized in the Indian Creek watershed.

5. Pesticides

The term *pesticide* includes any substance or mixture of substances intended for preventing, destroying, repelling, or mitigating any pest or intended for use as a plant regulator, defoliant, or desiccant. The principle pesticidal pollutants that may be detected in surface waters and in ground water are the active and inert ingredients and any persistent degradation products. Despite the documented benefits of using pesticides to control plant pests and enhance production, these chemicals may cause impairments to the uses of surface water and ground water. Some types of pesticides are resistant to degradation and may persist and accumulate in aquatic ecosystems.

Pesticides may harm the environment by eliminating or reducing populations of desirable organisms, including endangered species. Less than lethal effects include the behavioral and structural changes of an organism that jeopardize its survival. Bioconcentration is a phenomenon that occurs if an organism ingests more of a pesticide than it excretes. During its lifetime, the organism will accumulate a higher concentration of that pesticide than is present in the surrounding environment. When the organism is eaten by another animal higher in the food chain, the pesticide will then be passed to that animal, and on up the food chain to even higher level animals.

The primary routes of pesticide transport to aquatic systems are: direct application, runoff, aerial drift, volatilization and subsequent atmospheric deposition, and uptake by biota and subsequent movement in the food web. Pesticide losses are generally greatest when rainfall is intense and occurs shortly after pesticide application; a condition for which runoff and erosion losses are also greatest.

B. Livestock Grazing

Livestock grazing on pasturelands can contribute to nonpoint source pollution in streams. Documentation shows that cattle, given the opportunity, will spend a disproportionate amount of time in a riparian area as compared to drier upland areas. This may be 5 to 30 times higher than expected based on the extent of the riparian area. Features that contribute to higher use levels in riparian areas are:

- Higher forage volume and relative palatability in the riparian area as opposed to the uplands,
- Distance to water,
- Distance upslope to upland grazing sites, and
- Microclimatic features.

Although many of the riparian-fisheries-grazing studies have been deficient in design, measurement, or documentation, a great deal of case history and observational information has been accumulated. Concerning grazing impacts on riparian areas, four components were most often studied:

- Fish habitat in the aquatic system,
- Woody vegetation components of the riparian area relating to fish and bird habitat,
- Herbaceous utilization and grazing levels that can influence yields of plants, small mammals, and invertebrates,
- Watershed conditions of cover and soil compaction on the floodplain and runoff from upland range.

Effects of Livestock Grazing

The direct effects of livestock grazing have been summarized as follows:

- Higher stream temperatures from lack of sufficient woody streamside cover,
- Excessive sediment in the channel from bank and upland erosion,
- High coliform bacteria counts from upper watershed,
- Channel widening from hoof-caused bank sloughing and later erosion by water,
- Change in the form of the water column and the channel it flows in,
- Change, reduction, or elimination of vegetation,
- Elimination of riparian areas by channel degradation and lowering of the water table,
- Gradual stream channel trenching or braiding depending on soils and substrate composition with concurrent replacement of riparian vegetation with less desirable plant species.

In an extensive review of livestock impacts on riparian ecosystems, Oregon State University researchers documented many factors interrelated with grazing effects, primarily dealing with instream ecology, terrestrial wildlife, and riparian vegetation. However, as with many others, the authors were not able to find much information other than that abusive grazing practices are damaging to many features of riparian ecosystems. Little information is available on how well managed grazing affects riparian-stream systems. Criticisms of conventional grazing systems such as rest-rotation typically contain no information on actual grazing intensity or degree of plant utilization.

Permanent removal of grazing will not guarantee maximum herbaceous plant production. Researchers found that a protected Kentucky bluegrass meadow reached peak production in six years and then declined until production was similar to the adjacent area grazed season-long. Similar results were reported in northeastern Oregon. The accumulation of litter over a period of years seems to retard herbage production in wet meadow areas. Thus, some grazing of riparian areas could have beneficial effects to plant production.

Resistance of common riparian woody plants to defoliation has not been investigated. However, genera commonly represented in riparian areas such as dogwood, maple, cottonwood, willow, and birch appear to be more resistant to foliage and twig removal than genera common in the drier uplands. Light to moderate grazing generally appears to have little adverse effect and in some cases may stimulate growth. Severe overgrazing almost invariably is detrimental to willow communities. There are research reports that cattle alter the structure of high-altitude willow communities by changing the size, shape, volume, and quantity of live and dead stems per bush, and the spacing of plants. Researchers concluded that 10 to 12 years was not sufficient time for a riparian willow community to recover from a history of excessive grazing. Others have reported that reestablishment of acceptable wildlife habitat often occurred about 5 years after release of remnant shrubs from heavy grazing. Little information is available on how careful grazing affects willow communities except for observations that leaving a residual herbaceous stubble of about 4 inches usually results in little or no use of willows.

While vegetation recovery after release from excessive grazing generally can occur within 5 to 15 years, impacts on fishery environments go far beyond the riparian vegetation. Channel and bank morphology, instream cover, and water flow regimens are important factors. Little is known about the recovery time for these factors in different environments. Some researchers have suggested that sediment delivery to the stream was the most detrimental impact of trampling to fisheries. Others, however, pointed out that the retention of bank morphology and stability are probably more important. The maintenance of streambank structure and function is a key item in riparian-stream habitats from both fisheries and hydrologic standpoints. Fisheries biologists suggest several conditions for optimum fish habitat:

- At least 60 percent of the stream shaded between 10 a.m. and 4 p.m. during summer months.
- At least 80 percent of the streambank in stable condition.
- Not more than 15 percent of the gravel/rubble substrate covered by inorganic sediment.
- At least 80 percent of site potential for grass-forb, shrub, and tree cover.
- Instream cover should be about 50 percent of the total stream area.
- Overhanging banks on at least 50 percent of the streambanks.

Vegetation plays a dominant role not only in the erosional stability of streambanks but also in the rebuilding of degraded streambanks. Streamside vegetation serves as a natural trap to retain sediments during high flows. These sediments form the physical basis for new bank structure.

C. Manure Loading into Streams from Direct Fecal Deposits

Although sediment is generally considered the largest water quality problem from livestock grazing, nutrients and pathogens may also be of concern. The major nutrients coming from cattle are:

- nitrogen (N),
- phosphorus (P),
- and potassium (K).

The relatively benign Fecal Coliform (FC), and Fecal Streptococci (FS) bacteria are used to indicate the presence of possible pathogens.

To be considered a pollutant, nutrients and pathogens must reach a stream. Nutrients and pathogens can reach the water either by direct deposit or by overland transport during a runoff event. In most semi-arid environments runoff events are infrequent. Therefore, direct deposit of manure and urine into streams seems to be the most likely mode of nutrient or pathogen loading by livestock. The potential for this mode of contamination depends on time, density, and access.

The amount of time that livestock spend in or near streams can be variable as shown by studies at the San Joaquin Experimental Range (SJER) in the foothills of the Sierra Nevada Mountains in California and in Eastern Oregon (Table 1). The difference in drinking time in Table 1 may be that cattle drank from a trough at the SJER, and from streams in Eastern Oregon.

Table VI-4. Amount of time beef cattle spent drinking water as recorded in studies in California and Eastern Oregon.

Author	Drinking Time min/cow/day	Location
Wagnon 1963	3 to 6	SJER, California
Sneva 1970	17	Eastern Oregon
McInnis 1985	26	Eastern Oregon

In 1989, Oregon researchers observed the daily fecal deposits and amount of time spent in the creek by different classes of cattle and during different seasons in a high desert stream in Central Oregon (Table 2). They found that time spent in the creek and direct fecal deposits varied by season. This perennial stream is one to three feet wide and ½ to three feet deep. It is characterized by 100 to 300 yard wide riparian zones and bottom-land stringer meadows with slopes generally less than five percent dominated by Kentucky bluegrass with some alfalfa and clover. During the winter months some meadows were used for supplemental feeding areas. These meadows and riparian areas were part of a larger pasture that included uplands with 10 to 40 percent slopes consisting of juniper woodlands, sagebrush, and bunch grass. These uplands were dry and relatively unpalatable by early to mid summer.

Table VI-5. The amount of time cattle spent in the stream and the number of defecations directly into a high desert stream in central Oregon. Time in the stream includes drinking, loafing, etc. (From Larsen 1989)

Season	Cattle Class	# of Animals	Time Spent in Stream min/cow/day	Instream Fecal Deposit def/cow/day
Summer	cow/calf	17	11.2	0.41
Fall	cow/calf	18	3.0	0.19
Fall	bull	19	2.3	0.00
Winter	cow	109	5.6	0.20
Winter	yearling	40	0	0.14
Spring	cow/calf	116	3.9	0.17
Average		**5.2**	**0.19**	

Based on non-replicated observations for a two day period within each season. These values may not be applicable to other streams or grazing regimes and should be verified by further research.

Table VI-6. Estimates of the amount of manure, fecal coliform (FC), fecal streptococci (FS), nitrogen (N), phosphorus (P), and potassium (K) getting into the stream from grazing cattle based on one 1,000 lb beef cow.

Season	Manure			Bacteria		Nutrients	
Per Day	wet+(lb)	dry(lb)	FC(no.)	FS(no.)	N(lb)	P(lb)	K(lb)
Summer	2.05++	0.25	$1.3*10^{9}$	$2.4*10^{7}$	0.012	0.004	0.008
Fall	0.95++	0.11	$6.0*10^{8}$	$1.1*10^{7}$	0.005	0.002	0.004
Winter	1.00++	0.12	$5.4*10^{8}$	$1.2*10^{7}$	0.006	0.002	0.004
Spring	0.85++	0.10	$5.4*10^{8}$	$1.0*10^{7}$	0.005	0.002	0.003

+88% water
++Based on non-replicated observations for a two day period within each season.

This analysis was conducted by range scientists to obtain a rough idea of fecal pollution risk from livestock. These estimates are based on average defecation rates, nutrient contents, and bacteria concentrations in manure and may not reflect the real rates and contents at the site and time of the study.

The fecal loading rate of grazing cattle depends on the amount of time the cattle are grazing in a pasture with a stream. Using the values in Table VI-5 with estimates of defecation rates, nutrient content, and bacteria concentration in manure (Table VI-6), the potential nutrient and bacterial loading directly into the stream was estimated. The amount of manure, nitrogen (N), phosphorus (P), potassium (K), fecal coliform (FC) and fecal streptococci (FS), produced by beef cattle. Based on one 1,000 lb. beef cow.

- 12 defecations/day
- 60 lbs manure/day (88% water)
- 5 lbs manure/defecation (88% water)
- 0.34 lb N/day
- 0.11 lb P/day
- 0.24 lb K/day
- $3.84*10^{10}$ FC/day
- $7.2*10^{8}$ FS/day

Sources: Johnstone-Wallace and Kennedy 1944
Moore and Willrich 1982
Moore et al. 1988

The estimates in Table VI-6 indicate that the amount of manure loading into a stream for any given day, season, or year from one cow is quite small. However, there may still be a concern about pollution. As much as 95% of deposited manure will settle to the bottom of the stream within the first 50 meters (Biskie et al. 1988). The bacteria in the sediment may remain alive for several weeks (Sherer et al. 1992). Less is known about what happens to the nutrients that enter the stream in the manure.

Therefore, daily inputs from directly deposited feces may accumulate on the stream bottom. Any disturbance, such as peak flows, can resuspend sediment, creating high concentrations of bacteria, and possibly nutrients for a short period of time. The higher the density of livestock, the higher the concentration of pollution.

Any practice that reduces the amount of time cattle spend in a stream, and hence reduces the manure loading, will decrease the potential for adverse affects of water pollution from grazing livestock. It has been shown that providing a water trough as an alternative drinking source may reduce the instream fecal deposition during the winter by as much as 90 percent (Moore et al. 1993). In addition, Clawson (1993) found that summer stream use dropped from 4.7 min/cow/day to 0.9 min/cow/day and bottom land use dropped from 8.3 to 3.9 min/cow/day when a water trough was provided as an alternative water source. This indicates that reductions of creek use by cattle can be achieved without fencing them out of the creek, however exclusion by fencing is preferred.

D. Silviculture Managing Nonpoint Source Pollution from Forestry

Nearly 500 million acres of forested lands are managed for the production of timber in the United States. Although only a very small percentage of this land is harvested each year, forestry activities can cause significant water quality problems if improperly managed. The latest National Water Quality Inventory reports that forestry activities contribute to approximately 9 percent of the water quality problems in surveyed rivers and streams.

Sources of NPS pollution associated with forestry activities include removal of streamside vegetation, road construction and use, timber harvesting, and mechanical preparation for the planting of trees. Road construction and road use are the primary sources of NPS pollution on forested lands, contributing up to 90 percent of the total sediment from forestry operations. Harvesting trees in the area beside a stream can affect water quality by reducing the streambank shading that regulates water temperature and by removing vegetation that stabilizes the streambanks. These changes can harm aquatic life by limiting sources of food, shade, and shelter.

1. Preharvest Planning: Opportunities to Prevent NPS Pollution

To limit water quality impacts caused by forestry, public and private forest managers have developed and followed site-specific forest management plans. Following properly designed preharvest plans can result in logging activities that are both profitable and highly protective of water quality. Such plans address the full range of forestry activities that can cause NPS pollution. They clearly identify the area to be harvested; locate special areas of protection, such as wetlands and streamside vegetation; plan for the proper timing of forestry activities; describe management measures for road layout, design, construction, and maintenance, as well as for harvesting methods and forest regeneration.

Public meetings held under the authority of federal and state laws provide citizens with a good opportunity to review and comment on the development of forest management plans.

Preactivity surveys can help identify areas that might need special protection or management during forestry operations. Sensitive landscapes usually have steep slopes, a greater potential for landslides, sensitive rock formations, high precipitation levels, snowpack, or special ecological functions such as those provided by streamside vegetation. Forestry activities occurring in these areas have a high potential of affecting water quality.

Because most forestry activities disturb soil and contribute to erosion and runoff, timing operations carefully can significantly reduce their impact on water quality and aquatic life. Rainy seasons and fish migration and spawning seasons, for example, should be avoided when conducting forestry activities.

2. Establishing Streamside Management Areas (SMAs)

Plans often restrict forestry activities in vegetated areas near streams (also known as buffer strips or riparian zones), thereby establishing special SMAs. The vegetation in a SMA is highly beneficial to water quality and aquatic habitat. Vegetation in the SMA stabilizes streambanks, reduces runoff and nutrient levels in runoff, and traps sediment generated from upslope activities before it reaches surface waters. SMA vegetation moderates water temperature by shading surface water and provides habitat for aquatic life. For example, large trees provide shade while alive and provide aquatic habitat after they die and fall into the stream as large woody debris.

3. Managing Road Construction, Layout, Use, and Maintenance

Good road location and design can greatly reduce the transport of sediment to water bodies. Whenever possible, road systems should be designed to minimize road length, road width, and the number of places where water bodies are crossed. Roads should also follow the natural contours of the land and be located away from steep gradients, landslide-prone areas, and areas with poor drainage. Proper road maintenance and closure of unneeded roads can help reduce NPS impacts from erosion over the long term.

4. Managing Timber Harvesting

Most detrimental effects of harvesting are related to the access and movement of vehicles and machinery, and the dragging and loading of trees or logs. These effects include soil disturbance, soil compaction, and direct disturbance of stream channels. Poor harvesting and transport techniques can increase sediment production by 10 to 20 times and disturb as much as 40 percent of the soil surface. In contrast, careful logging disturbs as little as 8 percent of the soil surface. Careful selection of equipment and methods for transporting logs from the harvest area to areas where logs are gathered can significantly reduce the amount of soil disturbed and delivered to water bodies. Stream channels should be protected from logging debris at all times during harvesting operations.

5. Managing Replanting

Forests can be regenerated from either seed or seedlings. Seeding usually requires that the soil surface be prepared before planting. Seedlings can be directly planted with machines after minimal soil preparation. In either case, the use of heavy machinery can result in significant soil disturbance if not performed carefully.

D. Septic Systems

Sanitary sewers are not found in the Indian Creek watershed, forcing residents to use on-site sewage disposal systems. These disposal systems can work well in disposing of sewage, but when installed improperly or placed in poor geologic conditions, septic systems may have negative environmental impacts.

Approximately 1/3 of all homes in the United States dispose of their wastewater through septic systems, and about 25 percent of all new homes include septic tanks. Septic systems have been identified as local and regionalized sources of groundwater pollution and nonpoint source pollution to surface waters. The major pollutants associated with septic systems are nitrates and bacteria. Where sewers are not available, septic systems are usually the only alternative. Where traditional septic systems cannot be installed due to site constraints, there are alternatives such as low pressure dosing and sand filters. However these alternative methods are more expensive than the traditional septic system.

1. Septic Tank/Drainfield

The most common type of onsite sewage treatment system is the septic tank/drainfield system. Septic tank systems have made possible relatively high density residential development in areas where municipal wastewater treatment facilities are not available. The main function of the tank is to remove the solids from the wastewater. The water that enters the tank enters from a pipe that is connected to the home's main drain. Heavier solids settle to the bottom of the tank and pile up to create sludge. Lighter solids, like grease, float on the surface and form a mat of scum. Bacteria in the tank digest a vast amount of the heavier solids and grease. During this decomposition, some solids are liquified and leave the tank with the wastewater; thereby reducing the volume of the solids retained in the tank.

The remaining solids that accumulate in the tank must be pumped out of the tank at regular intervals. A recommended time interval for pumping is once about every three to five years. A properly designed and maintained tank should last 50 years or more.

The capacity of the tank varies depending on the number of bedrooms in the home. The average bedroom generates about 150 gallons of wastewater per day. That number is doubled to allow for a two day retention time in the tank so solids can settle, float, or biodegrade. A five bedroom home, for example, would require a 1500 gallon septic tank (150 gallons per bedroom per day times 2 days retention time times 5 bedrooms). Some common tank sizes are: 750, 1000, 1200, and 1500 gallons. Tank sizes other than these cost considerably more because they are not common.

The drainfield is made up of perforated plastic pipe or drain tile buried in a series of gravel lined trenches. The length and number of drain lines is determined by the type of soil and the number of bedrooms in each home. Wastewater seeps out of the holes in the pipe or the seams between tile sections and filters through a layer of rock to the soil, where the water is broken down by soil microbes, and filtered by a process of soil adsorption. Eventually this effluent reaches the groundwater below. The perforated pipe is installed level and is plugged with a cap at the end, so the water will drip out evenly along its length. In practice, however, the pipe sags and the liquid drips out of the lowest point. Once out of the pipe, the liquid spreads along the bottom of the leachline trench.

As the liquid disperses over the soil, it begins to grow a "biomat" that may become 1 to 2 inches. This "biomat" is composed of bacteria, both aerobic and anaerobic. The mat produced by aerobic is more permeable than the anaerobic, but neither mat is beneficial to the leachline. Over time, the mat may envelop the leachline. Eventually, if the daily flow of sewage into the leachline exceeds the amount of water that can infiltrate through the mat and whatever soil remains unclogged, the sewage begins to surface over the top of the adsorption field. This situation means the drainfield has failed. Drainfield failure also may be a result of a homeowner's neglect of the septic tank. Solids accumulate to the point that they are carried into the drainfield, clogging the lines.

2. Legal Aspects of Septic Tanks

The Health Departments of Green, Lawrence, Martin, and Monroe Counties are responsible for permitting septic systems in the Indian Creek watershed. Homeowners must have a site evaluation and a permit from the health department to build or modify a septic system. A property must meet the standards set forth before a permit is issued. Homeowners can be prosecuted for installing a sewage disposal system without a health department operation permit. Failure to abide by this regulation may result in a misdemeanor conviction or, in certain instances, more serious charges. Any agreement with a septic system installation firm should have a stipulation stating that no payment is given until the system passes inspection by the sanitation. The State of Indiana has regulations regarding the location of septic systems in relations to boundaries, wells and homes. The septic tank and drainfield must not be located under a patio, garage, storage building, parking lot, or other paved area.

3. Pollution from Septic Systems

A major concern with the design and usage of septic systems is the potential of polluting the groundwater. Pollution could come from metals, microbes, or other substances. The volume of water that flows into an average septic tank is on the order of 140 to 150 gallons per day per person. This amount can be broken down into percentages from typical household sources. On a percentage basis the sources can be broken down as follows:

Activity	Percentage
Toilets	22-45%
Laundry	4-26%
Baths	8-37%
Kitchen	6-13%
other sources	0-14%.

4. Efficiency of Soil Adsorption

The efficiency of soil adsorption is how much various parameters in the effluent from the septic tank are reduced compared to the influent. Many factors are involved in the efficiency of soil adsorption. Such factors as climate, soil type, hydraulic conductivity, precipitation, porosity, etc. contribute to how the effluent concentration is reduced in the soil.

A field study was conducted from December 1972, to February, 1974 in Ottawa, Ontario, Canada by Viraraghavan and Warnock. Soil samples were taken from various depths. From a 5 ft deep area of the underlying soil the following was found: -Soil was able to reduce 75-90% of the soluble organic carbon, Total Soluble Solids (TSS), Biological Oxygen Demand (BOD), and the Chemical Oxygen Demand (COD) -The levels of phosphate were reduced on the order of 25-50%. -High reductions in ammonia were found (80-90%) - The changing seasons had a noticeable effect on efficiency of the system. Greater efficiencies (80-90%) were observed during the late summer and early fall. This period was when the unsaturated depth of soil was the greatest. These efficiencies tended to decrease during the winter period when water levels in the soil began to rise. Decreases to 70-75% were observed for BOD and TSS and 20-35% for ammonia.

5. Groundwater Contamination

Groundwater contamination has occurred where there has been high densities of septic systems. Studies have shown that the groundwater has been contaminated by high amounts of organic contaminants from septic systems. Problems with septic systems are greater when communities that rely on subsurface disposal systems also depend on private wells for drinking water. As many as one-half of all septic tanks in operation are not functioning correctly. A common failure of a system is when the capacity of soil to absorb effluent is exceeded. When this occurs, the wastewater from the drain lines makes its way to the surface. This type of failure occurs when the soil is clogged with waste particles or other substances and it is harder for the water to move through the soil. When the system fails in this way and wastewater makes its way to the surface, water runoff from rain may wash the contaminants into surface waters or into inadequately sealed wells down gradient.

A more significant failure is when pollutants from the drain field move too quickly through the soil and potentially into the groundwater. When there is large volume of wastewater moving through the system, soils with high permeability can be rapidly overloaded with organic and inorganic chemicals and microbes, allowing rapid movement of pollutants into the groundwater. Special attention must be directed to the transport and fate of pollutants in the soil absorption phase when considering contamination of groundwater from septic systems.

Suspended solids in the effluent from the septic system are removed by filtration as the wastewater moves through the soil. This process of filtration varies with the soil type, the size of the particles, soil texture, and the rate of the water flow. The key chemical processes governing the movement of particles from the effluent through the soil are ion exchange, adsorption, and chemical precipitation.

a. Inorganic Contaminants

Some potential inorganic contaminants from septic systems include nitrogen, chlorides, phosphorous, and metals.

Nitrogen

The organic form of nitrogen is converted to the ammonium form since anaerobic conditions occur in the septic tank. The amount of nitrogen in the effluent from the tank averages about 40 mg/L and consists roughly of 75% in the NH_4^+ and 25% in the organic form. Nitrogen contamination is of concern because it causes eutrophication in surface waters and is hazardous to human health if ingested in high concentrations. The fate and movement of nitrogen in the soil from septic systems is dependent on the form of the nitrogen and biological conversions that may take place. The most common form of nitrogen entering the soil, ammonium (NH_4^+) form, undergoes the process of nitrification. In the process of nitrification, ammonium is converted to nitrite and then into nitrate (NO_3^-). This process is an aerobic reaction carried out by obligate autotrophic organisms.

Denitrification also occurs in the soil under the septic system. Denitrification is the reduction of NO_3^- to N_2O or N_2 by obligate facultative heterotrophs. In the absence of O_2, NO_3^- acts as the acceptor of electrons generated in the microbial decomposition of an energy source. Since ammonium is the most common form of nitrogen present, nitrification must occur before denitrification can. Nitrate NO_3^- is the most mobile form of nitrogen in both saturated and unsaturated soil conditions. The immobilization of nitrates is done by the uptake of it by plants in the immediate area. The nitrates move with water with little transformation and can travel long distances if the right conditions are present.

Chlorides

Chlorides are very common and are naturally present in surface and groundwater, and are also found in wastewaters. Chlorides are difficult to remove from wastewasters and both septic systems and wastewater treatment plants are unable to remove them. The concentration of chlorides in wastewater varies with the natural quality of the water supply. Since chlorides are anionic and mobile, they can be used as tracers of septic tank system pollution. (Canter & Knox)

Phosphorus

Most of the influent phosphorus in the organic and phosphate forms is converted to soluble orthophosphate by the anaerobic process occurring in the septic tank. Usually phosphorus does not reach the groundwater because it is strongly retained in soils. Phosphorus is not really harmful to humans but it is a major contributor to eutrophication in surface waters.

b. Other Inorganic Contaminants

Metals in the effluents from septic tank systems may be responsible for the contamination of shallow water supply sources, such as where there is a high groundwater table. In some areas, the levels of arsenic, iron, lead, mercury, and manganese were found at levels higher than what is recommended.

The soil type is an important factor in all heavy metal fixation reactions. Both soil texture and pH are important in the fixation of metals by the soil. Finer textured soil immobilizes trace and heavy metals to a greater extent as compared with those with coarse texture. Finer textured soils usually have a greater action exchange capacity due to their larger surface area. The transport of lead, zinc, mercury, and nickel has been linked to the texture of soil. The degree of fixation is a function of the pH. Soil pH influences the immobilization of lead, mercury, copper, and zinc.

c. Microorganisms

Microorganisms usually do not contaminate groundwater sources. The main limitation to movement of microbes through the soil is the physical filtration of bacteria and other microbes. It is the factor that usually limits the travel distances. Soil conditions such as no nutrients, drying, and antagonistic organisms' secretions also determine the travel distances.

VII. ALTERNATIVES

1. Agricultural BMPs

A. Managing Nonpoint Source Pollution from Agriculture

The United States has over 330 million acres of agricultural land that produce an abundant supply of low-cost, nutritious food and other products. American agriculture is noted worldwide for its high productivity, quality, and efficiency in delivering goods to the consumer. However, when improperly managed, agricultural activities can affect water quality. The most recent National Water Quality Inventory reports that agricultural nonpoint source (NPS) pollution is the leading source of water quality impacts to surveyed rivers and lakes, the third largest source of impairments to surveyed estuaries, and also a major contributor to ground water contamination and wetlands degradation.

Agricultural activities that cause NPS pollution include confined animal facilities, grazing, plowing, pesticide spraying, irrigation, fertilizing, planting, and harvesting. The major agricultural NPS pollutants that result from these activities are sediment, nutrients, pathogens, pesticides, and salts.

Agricultural activities also can damage habitat and stream channels. Agricultural impacts on surface water and ground water can be minimized by properly managing activities that can cause NPS pollution. Numerous government programs are available to help people design and pay for management approaches to prevent and control NPS pollution. For example, over 40 percent of section 319 Clean Water Act grants were used to control agricultural NPS pollution. Also, several U.S. Department of Agriculture and state-funded programs provide cost-share, technical assistance, and economic incentives to implement NPS pollution management practices. Many people use their own resources to adopt technologies and practices to limit water quality impacts caused by agricultural activities.

B. Managing Sedimentation.

Sedimentation occurs when wind or water runoff carries soil particles from an area, such as a farm field, and transports them to a water body, such as a stream or lake. Excessive sedimentation clouds the water, which reduces the amount of sunlight reaching aquatic plants; covers fish spawning areas and food supplies; and clogs the gills of fish. In addition, other pollutants like phosphorus, pathogens, and heavy metals are often attached to the soil particles and wind up in the water bodies with the sediment. Farmers and ranchers can reduce erosion and sedimentation by 20 to 90 percent by applying management measures to control the volume and flow rate of runoff water, keep the soil in place, and reduce soil transport.

C. Managing Nutrients.

Nutrients such as phosphorus, nitrogen, and potassium in the form of fertilizers, manure, sludge, irrigation water, legumes, and crop residues are applied to enhance production. When they are applied in excess of plant needs, nutrients can wash into aquatic ecosystems where they can cause excessive plant growth, which reduces swimming and boating opportunities, creates a foul taste and odor in drinking water, and kills fish. In drinking water, high concentrations of nitrate can cause methemoglobinemia, a potentially fatal disease in infants also known as blue baby syndrome. Farmers can implement nutrient management plans that help maintain high yields and save money on the use of fertilizers while reducing NPS pollution.

D. Managing Confined Animal Facilities.

By confining animals to areas or lots, farmers and ranchers can efficiently feed and maintain livestock. But these confined areas become major sources of animal waste. Runoff from poorly managed facilities can carry pathogens (bacteria and viruses), nutrients, and oxygen-demanding substances that contaminate shellfishing areas and other major water quality problems. Ground water can also be contaminated by seepage. Discharges can be limited by storing and managing facility wastewater and runoff with an appropriate waste management system.

E. Managing Pesticides.

Pesticides, herbicides, and fungicides are used to kill pests and control the growth of weeds and fungus. These chemicals can enter and contaminate water through direct application, runoff, wind transport, and atmospheric deposition. They can kill fish and wildlife, poison food sources, and destroy the habitat that animals use for protective cover. To reduce NPS contamination from pesticides, people can apply Integrated Pest Management (IPM) techniques based on the specific soils, climate, pest history, and crop for a particular field. IPM helps limit pesticide use and manages necessary applications to minimize pesticide movement from the field.

2. Grazing Management

Overgrazing exposes soils, increases erosion, encourages invasion by undesirable plants, destroys fish habitat, and reduces the filtration of sediment necessary for building streambanks, wet meadows, and floodplains. To reduce the impacts of grazing on water quality, farmers and ranchers can adjust grazing intensity, keep livestock out of sensitive areas, provide alternative sources of water and shade, and revegetated pastureland. Protect pasture and other grazing lands by implementing one or more of the following to protect sensitive areas (such as streambanks, wetlands, ponds, and riparian zones):

- Exclude livestock,
- Provide stream crossings or hardened/rocked watering access for drinking,
- Provide alternative drinking water locations,
- Locate salt and additional shade, if needed, away from sensitive areas,
- Use improved grazing management (e.g., herding) to reduce the physical disturbance and reduce direct loading of animal waste and sediment caused by livestock

The focus of grazing management is typically on the riparian zone, yet the control of erosion from pasture, and other grazing lands above the riparian zone is also encouraged.

Application of this management will reduce the physical disturbance to sensitive areas and reduce the discharge of sediment, animal waste, nutrients, and chemicals to surface waters.

The key options to consider when developing a comprehensive grazing management approach at a particular location include the development of one or more of the following:

- Grazing management systems. These systems ensure proper grazing use through:
  - Grazing frequency (includes complete rest);
  - Livestock stocking rates;
  - Livestock distribution;
  - Timing (season of forage use) and duration of each rest and grazing period;
  - Livestock kind and class; and
  - Forage use allocation for livestock and wildlife.
- Proper water and salt supplement facilities.
- Livestock access control.
- Pasture rehabilitation.

For any grazing management system to work, it must be tailored to fit the needs of the vegetation, terrain, class or kind of livestock, and particular operation involved. Areas should be provided for livestock watering, salting, and shade that are located away from streambanks and riparian zones where necessary and practical. This will be accomplished by managing livestock grazing and providing facilities for water, salt, and shade as needed.

Special attention must be given to grazing management in riparian and wetland areas if management measure objectives are to be met. Riparian areas are defined as vegetated ecosystems along a waterbody through which energy, materials, and water pass. Riparian areas characteristically have a high water table and are subject to periodic flooding and influence from the adjacent waterbody.

The health of the riparian system, and thus the quality of water, is dependent on the use, management, and condition of the related uplands. Therefore, the proper management of riparian and wetland ecosystems will involve the correct management of livestock grazing and other land uses in the total watershed.

Conservation management systems (CMS) include a combination of conservation practices and management that achieves a level of treatment of the five natural resources including soil, water, air, plants, and animals.

The range and pasture components of a CMS address erosion control, proper grazing, adequate pasture stand density, and range condition. Minimum criteria pertaining to range and pasture under a resource management system (RMS) are applied to achieve environmental objectives, conserve natural resources, and prevent soil degradation.

Available information documents the beneficial effects of improved grazing management. Specifically, the available information shows that aquatic habitat conditions are improved with proper livestock management; pollution from livestock is decreased by reducing the amount of time spent in the stream through the provision of supplemental water; and sediment delivery is reduced through the proper use of vegetation, streambank protection, planned grazing systems, and livestock management.

Hubert et al. (1985) showed in plot studies in Wyoming that livestock exclusion and reductions in stocking rates can result in improved habitat conditions for brook trout. In this study, the primary vegetation was willows. Pete Creek stocking density was 7.88 ac/AUM (acres per animal unit month), and Cherry Creek stocking density was 10 cows per acre.

Platts and Nelson (1989) used plot studies in Utah to evaluate the effects of livestock exclusion on riparian plant communities and streambanks. Several streambank characteristics that are related to the quality of fish habitat were measured, including bank stability, stream shore depth, streambank angle, undercut, overhang, and streambank alteration. The results clearly show better fish habitat in the areas where livestock were excluded.

Kauffman et al. (1983) showed that fall cattle grazing decreases the standing phytomass of some riparian plant communities by as much as 21 percent versus areas where cattle are excluded, while causing increases for other plant communities. This study, conducted in Oregon from 1978 to 1980, incorporated stocking rates of 3.2 to 4.2 ac/AUM.

Eckert and Spencer (1987) studied the effects of a three-pasture, rest-rotation management plan on the growth and reproduction of heavily grazed native bunchgrasses in Wyoming. The results indicated that range improvement under this otherwise appropriate rotation grazing system is hindered by heavy grazing. Stocking rates on the study plots ranged from 525 to 742 cow-calf AUMs.

In a literature review, Van Poollen and Lacey (1979) showed that herbage production was greater for managed grazing versus continuous grazing, greater for moderate versus heavy intensity grazing, and greater for light- versus moderate-intensity grazing.

McDougald et al. (1989) tested the effects of moving supplemental feeding locations on riparian areas of hardwood range in California. With stocking rates of approximately 1ac/AUM, they found that moving supplemental feeding locations away from water sources into areas with high amounts of forage greatly reduces the impacts of cattle on riparian areas.

Miner et al. (1991) showed that the provision of supplemental water facilities reduced the time each cow spent in the stream within 4 hours of feeding from 14.5 minutes to 0.17 minutes (8-day average). This pasture study in Oregon showed that the 90 cows without supplemental water spent a daily average of 25.6 minutes per cow in the stream. For the 60 cows that were provided a supplemental water tank, the average daily time in the stream was 1.6 minutes per cow, while 11.6 minutes were spent at the water tank. Based on this study, the authors expect that decreased time spent in the stream will decrease bacterial loading from the cows.

Tiedemann et al. (1988) studied the effects of four grazing strategies on bacteria levels in 13 Oregon watersheds in the summer of 1984. Results indicate that lower fecal coliform levels can be achieved at stocking rates of about 20 ac/AUM if management for livestock distribution, fencing, and water developments are used. The study also indicates that, even with various management practices, the highest fecal coliform levels were associated with the higher stocking rates (6.9 ac/AUM).

Lugbill (1990) estimates that stream protection in the Potomac River Basin will reduce total nitrogen (TN) and total phosphorus (TP) loads by 15 percent, while grazing land protection and permanent vegetation improvement will reduce TN and TP loads by 60 percent. Owens et al. (1982) measured nitrogen losses from an Ohio pasture under a medium-fertility, 12-month pasture program from 1974 to 1979. The results included no measurable soil loss from three watersheds under summer grazing only, and increased average TN concentrations and total soluble N loads from watersheds under summer grazing and winter feeding versus watersheds under summer grazing only.

Data from a comparison of the expected effectiveness of various grazing and streambank practices in controlling sedimentation in the Molar Flats Pilot Study Area in Fresno County, California indicate that planned grazing systems are the most effective single practice for reducing sheet and rill erosion.

Streambank protection is expected to be the most effective single practice for reducing streambank erosion. Other practices evaluated are proper grazing use, deferred grazing, emergency seeding, and livestock exclusion.

A. Pasture Management Practices

The following practices are described for illustrative purposes only. State programs need not require implementation of these practices. However, as a practical matter, EPA anticipates that the management measure set forth above generally will be implemented by applying one or more management practices appropriate to the source, location, and climate. The practices set forth below have been found by EPA to be representative of the types of practices that can be applied successfully to achieve the management measure described above.

The U.S. Soil Conservation Service practice number and definition are provided for each management practice, where available. Also included in italics are SCS statements describing the effect each practice has on water quality.

1. Grazing Management System Practices

Appropriate grazing management systems ensure proper grazing use by adjusting grazing intensity and duration to reflect the availability of forage and feed designated for livestock uses, and by controlling animal movement through the operating unit of range or pasture. Proper grazing use will maintain enough live vegetation and litter cover to protect the soil from erosion;

will achieve riparian and other resource objectives; and will maintain or improve the quality, quantity, and age distribution of desirable vegetation. Practices that accomplish this are:

a. Deferred grazing (352): Postponing grazing or resting grazing land for prescribed period.

In areas with bare ground or low percent ground cover, deferred grazing will reduce sediment yield because of increased ground cover, less ground surface disturbance, improved soil bulk density characteristics, and greater infiltration rates. Areas mechanically treated will have less sediment yield when deferred to encourage re-vegetation. Animal waste would not be available to the area during the time of deferred grazing and there would be less opportunity for adverse runoff effects on surface or aquifer water quality. As vegetative cover increases, the filtering processes are enhanced, thus trapping more silt and nutrients as well as snow if climatic conditions for snow exist. Increased plant cover results in a greater uptake and utilization of plant nutrients.

b. Planned grazing system (556): A practice in which two or more grazing units are alternately rested and grazed in a planned sequence for a period of years, and rest periods may be throughout the year or during the growing season of key plants.

Planned grazing systems normally reduce the system time livestock spend in each pasture. This increases quality and quantity of vegetation. As vegetation quality increases, fiber content in manure decreases which speeds manure decomposition and reduces pollution potential. Freeze-thaw, shrink-swell, and other natural soil mechanisms can reduce compacted layers during the absence of grazing animals. This increases infiltration, increases vegetative growth, slows runoff, and improves the nutrient and moisture filtering and trapping ability of the area.

Decreased runoff will reduce the rate of erosion and movement of sediment and dissolved and sediment-attached substances to downstream water courses. No increase in ground water pollution hazard would be anticipated from the use of this practice.

c. Proper grazing use (528): Grazing at an intensity that will maintain enough cover to protect the soil and maintain or improve the quantity and quality of desirable vegetation.

Increased vegetation slows runoff and acts as a sediment filter for sediments and sediment attached substances, uses more nutrients, and reduces raindrop splash. Adverse chemical effects should not be anticipated from the use of this practice.

d. Proper woodland grazing (530): Grazing wooded areas at an intensity that will maintain adequate cover for soil protection and maintain or improve the quantity and quality of trees and forage vegetation.

This practice is applicable on wooded areas producing a significant amount of forage that can be harvested without damage to other values. In these areas there should be no *detrimental effects on the quality of surface and ground water. Any time this practice is applied there must be a detailed management and grazing plan.*

e. Pasture and hayland management (510): Proper treatment and use of pasture or hayland.

With the reduced runoff there will be less erosion, less sediment and substances transported to the surface waters. The increased infiltration increases the possibility of soluble substances leaching into the ground water.

2. Alternate Water Supply Practices

Providing water and salt supplement facilities away from streams will help keep livestock away from streambanks and riparian zones. The establishment of alternate water supplies for livestock is an essential component of this measure when problems related to the distribution of livestock occur in a grazing unit. In most western states, securing water rights may be necessary. Access to a developed or natural water supply that is protective of streambank and riparian zones can be provided by using the stream crossing (interim) technology to build a watering site. In some locations, artificial shade may be constructed to encourage use of upland sites for shading and loafing. Providing water can be accomplished through the following Soil Conservation Service practices and the stream crossing (interim) practice (practice "m") of the following section. Descriptions have been modified to meet CZM needs:

a. Pipeline (516): Pipeline installed for conveying water for livestock or for recreation.

Pipelines may decrease sediment, nutrient, organic, and bacteria pollution from livestock. Pipelines may afford the opportunity for alternative water sources other than streams and lakes, possibly keeping the animals away from the stream or impoundment. This will prevent bank destruction with resulting sedimentation, and will reduce animal waste deposition directly in the water. The reduction of concentrated livestock areas will reduce manure solids, nutrients, and bacteria that accompany surface runoff.

b. Pond (378): A water impoundment made by constructing a dam or an embankment or by excavation of a pit or dugout.

Ponds may trap nutrients and sediment that wash into the basin. This removes these substances from downstream. Chemical concentrations in the pond may be higher during the summer months. By reducing the amount of water that flows in the channel downstream, the frequency of flushing of the stream is reduced and there is a collection of substances held temporarily within the channel. A pond may cause more leachable substance to be carried into the ground water.

c. Trough or tank (614): A trough or tank, with needed devices for water control and waste water disposal, installed to provide drinking water for livestock.

By the installation of a trough or tank, livestock may be better distributed over the pasture, grazing can be better controlled, and surface runoff reduced, thus reducing erosion. By itself this practice will have only a minor effect on water quality; however when coupled with other conservation practices, the beneficial effects of the combined practices may be large. Each site and application should be evaluated on their own merits.

d. Well (642): A well constructed or improved to provide water for irrigation, livestock, wildlife, or recreation.

When water is obtained, if it has poor quality because of dissolved substances, its use in the surface environment or its discharge to downstream water courses the surface water will be degraded. The location of the well must consider the natural water quality and the hazards of its use in the potential contamination of the environment. Hazard exists during well development and its operation and maintenance to prevent aquifer quality damage from the pollutants through the well itself by back flushing, or accident, or flow down the annular spacing between the well casing and the bore hole.

e. Spring development (574): Improving springs and seeps by excavating, cleaning, capping, or providing collection and storage facilities.

There will be negligible long-term water quality impacts with spring developments. Erosion and sedimentation may occur from any disturbed areas during and immediately after construction, but should be short-lived. These sediments will have minor amounts of adsorbed nutrients from soil organic matter.

3. Livestock Access Limitation Practices

It may be necessary to minimize livestock access to streambanks, ponds or lakeshores, and riparian zones to protect these areas from physical disturbance. This could also be accomplished by establishing special use pastures to manage livestock in areas of concentration. Practices include:

a. Fencing (382): Enclosing or dividing an area of land with a suitable permanent structure that acts as a barrier to livestock, big game, or people (does not include temporary fences).

Fencing is a practice that can be on the contour or up and down slope. Often a fence line has grass and some shrubs in it. When a fence is built across the slope it will slow down runoff, and cause deposition of coarser grained materials reducing the amount of sediment delivered downslope. Fencing may protect riparian areas that act as sediment traps and filters along water channels and impoundments.

Livestock have a tendency to walk along fences. The paths become bare channels which concentrate and accelerate runoff causing a greater amount of erosion within the path and where the path/channel outlets into another channel. This can deliver more sediment and *associated pollutants to surface waters. Fencing can have the effect of concentrating livestock in small areas, causing a concentration of manure that may wash off into the stream, thus causing surface water pollution.*

b. Livestock exclusion (472): Excluding livestock from an area not intended for grazing.

Livestock exclusion may improve water quality by preventing livestock from being in the water or walking down the banks, and by preventing manure deposition in the stream. The amount of sediment and manure may be reduced in the surface water. This practice prevents compaction of the soil by livestock and prevents losses of vegetation and undergrowth. This may maintain or increase evapotranspiration. Increased permeability may reduce erosion and lower sediment and substance transportation to the surface waters. Shading along streams and channels resulting from the application of this practice may reduce surface water temperature.

c. Stream crossing (interim): A stabilized area to provide access across a stream for livestock and farm machinery.

The purpose is to provide a controlled crossing or watering access point for livestock along with access for farm equipment, control bank and streambed erosion, reduce sediment and enhance water quality, and maintain or improve wildlife habitat.

4. Vegetative Stabilization Practices

It may be necessary to improve or reestablish the vegetative cover on range and pastures to reduce erosion rates. The following practices can be used to reestablish vegetation:

a. Pasture and hayland planting (512): Establishing and reestablishing long-term stands of adapted species of perennial, biannual, or reseeding forage plants. (Includes pasture and hayland renovation. Does not include grassed waterways or outlets or cropland.)

The long-term effect will be an increase in the quality of the surface water due to reduced erosion and sediment delivery. Increased infiltration and subsequent percolation may cause more soluble substances to be carried to ground water.

b. Range seeding (550): Establishing adapted plants by seeding on native grazing land. (Range does not include pasture and hayland planting.)

Increased erosion and sediment yield may occur during the establishment of this practice. This is a temporary situation and sediment yields decrease when reseeded area becomes established. If chemicals are used in the reestablishment process, chances of chemical runoff into downstream water courses are reduced if application is applied according to label instructions. After establishment of the grass cover, grass sod slows runoff, acts as a filter to trap sediment, sediment attached substances, increases infiltration, and decreases sediment yields.

c. Critical area planting (342): Planting vegetation, such as trees, shrubs, vines, grasses, or legumes, on highly erodible or critically eroding areas. (Does not include tree planting mainly for wood products.)

This practice may reduce soil erosion and sediment delivery to surface waters. Plants may take up more of the nutrients in the soil, reducing the amount that can be washed into surface waters or leached into ground water.

During grading, seedbed preparation, seeding, and mulching, large quantities of sediment and associated chemicals may be washed into surface waters prior to plant establishment.

d. Brush (and weed) management (314): Managing and manipulating stands of brush (and weeds) on range, pasture, and recreation and wildlife areas by mechanical, chemical, or biological means or by prescribed burning. (Includes reducing excess brush (and weeds) to restore natural plant community balance and manipulating stands of undesirable plants through selective and patterned treatments to meet specific needs of the land and objectives of the land user.)

Improved vegetation quality and the decrease in runoff from the practice will reduce the amount of erosion and sediment yield. Improved vegetative cover acts as a filter strip to trap the movement of dissolved and sediment attached substances, such as nutrients and chemicals from entering downstream water courses. Mechanical brush management may initially increase sediment yields because of soil disturbances and reduced vegetative cover. This is temporary until revegetation occurs.

e. Prescribed burning (338): Applying fire to predetermined areas under conditions under which the intensity and spread of the fire are controlled.

When the area is burned in accordance with the specifications of this practice the nitrates with the burned vegetation will be released to the atmosphere. The ash will contain phosphorous and potassium which will be in a relatively highly soluble form. If a runoff event occurs soon after the burn there is a probability that these two materials may be transported into the ground water or into the surface water. When in a soluble state the phosphorous and potassium will be more difficult to trap and hold in place. When done on range grasses the growth of the grasses is increased and there will be an increased tie-up of plant nutrients as the grasses' growth is accelerated.

B. Selection of Practices

The selection of management practices should be based on an evaluation of current conditions, problems identified, quality criteria, and management goals. Successful resource management on range and pasture includes appropriate application of a combination of practices that will meet the needs of the range and pasture ecosystem (i.e., the soil, water, air, plant, and animal (including fish and shellfish) resources) and the objectives of the land user.

For a sound grazing land management system to function properly and to provide for a sustained level of productivity, the following should be considered:

- Know the key factors of plant species management, their growth habits, and their response to different seasons and degrees of use by various kinds and classes of livestock.

- Know the demand for, and seasons of use of, forage and browse by wildlife species.

- Know the amount of plant residue or grazing height that should be left to protect grazing land soils from wind and water erosion, provide for plant regrowth, and provide the riparian vegetation height desired to trap sediment or other pollutants.

- Know the range site production capabilities and the pasture suitability group capabilities so an initial stocking rate can be established.

- Know how to use livestock as a tool in the management of the range ecosystems and pastures to ensure the health and vigor of the plants, soil tilth, proper nutrient cycling, erosion control, and riparian area management, while at the same time meeting livestock nutritional requirements. Establish grazing unit sizes, watering, shade and salt locations, etc. to secure optimum livestock distribution and proper vegetation use.

- Provide for livestock herding, as needed, to protect sensitive areas from excessive use at critical times.

- Encourage proper wildlife harvesting to ensure proper population densities and forage balances.

- Know the livestock diet requirements in terms of quantity and quality to ensure that there are enough grazing units to provide adequate livestock nutrition for the season and the kind and classes of animals on the farm/ranch.

- Maintain a flexible grazing system to adjust for unexpected environmentally and economically generated problems.

- Special requirements to protect threatened or endangered species.

C. Costs

Much of the cost associated with implementing grazing management practices is due to fencing installation, water development, and system maintenance. Costs vary according to region and type of practice. Generally, the more components or structures a practice requires, the more expensive it is. However, cost-share may be available from the USDA and other Federal agencies for these practices.

Grazing Facilities

Principal direct costs of providing grazing facilities vary from relatively low variable costs of dispersed salt blocks to higher capital and maintenance costs of supplementary water supply improvements. Improving the distribution of grazing pressure by herding or strategically locating grazing facilities to draw cattle away from streamside areas can result in improved utilization of existing forage.

The availability and feasibility of supplementary water development varies considerably between arid western areas and humid eastern areas, but costs for water development, including spring development and pipeline watering, are similar.

Livestock Exclusion

Principal direct costs of livestock exclusion are the capital and maintenance costs for fencing to restrict access to streamside areas or the cost of herders to achieve the same results. In addition, there may be an indirect cost of the forage that is removed from grazing by exclusion.

There is considerable difference between multistrand barbed wire, chiefly used for perimeter fencing and permanent stream exclusion and diversions, and single- or double-strand smoothwire electrified fencing used for stream exclusion and temporary divisions within permanent pastures. The latter may be all that is needed to accomplish most livestock exclusion in smaller, managed pastures in the East.

Improvement/Reestablishment

Principal direct costs of improving or reestablishing grazing land include the costs of seed, fertilizer, and herbicides needed to establish the new forage stand and the labor and machinery costs required for preparation, planting, cultivation, and weed control. An indirect cost may be the forage that is removed from grazing during the reestablishment work and rest for seeding establishment.

Overall Costs of the Grazing Management Measure

Since the exact combination of practices needed to implement the management measure depends on site-specific conditions that are highly variable, the overall cost of the measure is best estimated from similar combinations of practices applied under the Agricultural Conservation Program (ACP), Rural Clean Water Program (RCWP), and similar activities.

3. Silviculture BMPs

A. Managing Nonpoint Source Pollution from Forestry

Nearly 500 million acres of forested lands are managed for the production of timber in the United States. Although only a very small percentage of this land is harvested each year, forestry activities can cause significant water quality problems if improperly managed. The latest National Water Quality Inventory reports that forestry activities contribute to approximately 9 percent of the water quality problems in surveyed rivers and streams. Sources of NPS pollution associated with forestry activities include removal of streamside vegetation, road construction and use, timber harvesting, and mechanical preparation for the planting of trees. Road construction and road use are the primary sources of NPS pollution on forested lands, contributing up to 90 percent of the total sediment from forestry operations. Harvesting trees in the area beside a stream can affect water quality by reducing the streambank shading that regulates water temperature and by removing vegetation that stabilizes the streambanks. These changes can harm aquatic life by limiting sources of food, shade, and shelter.

Preharvest Planning: Opportunities to Prevent NPS Pollution

To limit water quality impacts caused by forestry, public and private forest managers have developed and followed site-specific forest management plans. Following properly designed preharvest plans can result in logging activities that are both profitable and highly protective of water quality. Such plans address the full range of forestry activities that can cause NPS pollution. They clearly identify the area to be harvested; locate special areas of protection, such as wetlands and streamside vegetation; plan for the proper timing of forestry activities; describe management measures for road layout, design, construction, and maintenance, as well as for harvesting methods and forest regeneration.

Public meetings held under the authority of federal and state laws provide citizens with a good opportunity to review and comment on the development of forest management plans.

B. Factors Considered in the Preharvest Plan

Surveying the Site. Preactivity surveys can help identify areas that might need special protection or management during forestry operations. Sensitive landscapes usually have steep slopes, a greater potential for landslides, sensitive rock formations, high precipitation levels, or special ecological functions such as those provided by streamside vegetation. Forestry activities occurring in these areas have a high potential of affecting water quality.

Timing. Because most forestry activities disturb soil and contribute to erosion and runoff, timing operations carefully can significantly reduce their impact on water quality and aquatic life. Rainy seasons and fish migration and spawning seasons, for example, should be avoided when conducting forestry activities.

Establishing Streamside Management Areas (SMAs). Plans often restrict forestry activities in vegetated areas near streams (also known as buffer strips or riparian zones), thereby establishing special SMAs. The vegetation in a SMA is highly beneficial to water quality and aquatic habitat. Vegetation in the SMA stabilizes streambanks, reduces runoff and nutrient levels in runoff, and traps sediment generated from upslope activities before it reaches surface waters. SMA vegetation moderates water temperature by shading surface water and provides habitat for aquatic life. For example, large trees provide shade while alive and provide aquatic habitat after they die and fall into the stream as large woody debris.

Managing Road Construction, Layout, Use, and Maintenance. Good road location and design can greatly reduce the transport of sediment to water bodies. Whenever possible, road systems should be designed to minimize road length, road width, and the number of places where water bodies are crossed. Roads should also follow the natural contours of the land and be located away from steep gradients, landslide-prone areas, and areas with poor drainage. Proper road maintenance and closure of unneeded roads can help reduce NPS impacts from erosion over the long term.

Managing Timber Harvesting. Most detrimental effects of harvesting are related to the access and movement of vehicles and machinery, and the dragging and loading of trees or logs. These effects include soil disturbance, soil compaction, and direct disturbance of stream channels. Poor harvesting and transport techniques can increase sediment production by 10 to 20 times and disturb as much as 40 percent of the soil surface. In contrast, careful logging disturbs as little as 8 percent of the soil surface. Careful selection of equipment and methods for transporting logs from the harvest area to areas where logs are gathered can significantly reduce the amount of soil disturbed and delivered to water bodies. Stream channels should be protected from logging debris at all times during harvesting operations.

Managing Replanting. Forests can be regenerated from either seed or seedlings. Seeding usually requires that the soil surface be prepared before planting. Seedlings can be directly planted with machines after minimal soil preparation. In either case, the use of heavy machinery can result in significant soil disturbance if not performed carefully.

4. Homeowner BMPs

The well-known stories about environmental problems tend to focus on big, recognizable targets such as smoking industrial facilities, leaking toxic waste dumps, and messy oil spills. As a result, people often forget about water pollution caused by smaller nonpoint sources--especially pollution at the household level.

However, nonpoint source (NPS) pollution is the Nation's leading source of water quality degradation. Although individual homes might contribute only minor amounts of NPS pollution, the combined effect of an entire neighborhood can be serious. These include eutrophication, sedimentation, and contamination with unwanted pollutants.

To prevent and control NPS pollution, households can learn about the causes of such pollution and take the appropriate (and often money-saving) steps to limit runoff and make sure runoff stays clean.

A. Limit Paved Surfaces

Urban and suburban landscapes are covered by paved surfaces like sidewalks, parking lots, roads, and driveways. They prevent water from percolating down into the ground, cause runoff to accumulate, and funnel into storm drains at high speeds. When quickly flowing runoff empties into receiving waters, it can severely erode streambanks. Paved surfaces also transfer heat to runoff, thereby increasing the temperature of receiving waters. Native species of fish and other aquatic life cannot survive in these warmer waters.

To limit NPS pollution from paved surfaces households can substitute alternatives to areas traditionally covered by nonporous surfaces. Grasses and natural ground cover, for example, can be attractive and practical substitutes for asphalt driveways, walkways, and patios. Some homes effectively incorporate a system of natural grasses, trees, and mulch to limit continuous impervious surface area. Wooden decks, gravel or brick paths, and rock gardens keep the natural ground cover intact and allow rainwater to slowly seep into the ground.

B. Landscape With Nature

Altering the natural contours of yards during landscaping and planting with non-native plants that need fertilizer and extra water can increase the potential for higher runoff volumes, increase erosion, and introduce chemicals into the path of runoff. In contrast, xeriscape landscaping provides households with a framework that can dramatically reduce the potential for NPS pollution.

Xeriscape incorporates many environmental factors into landscape design--soil type, use of native plants, practical turf areas, proper irrigation, mulches, and appropriate maintenance schedules. By using native plants that are well-suited to a regions climate and pests, xeriscape drastically reduces the need for irrigation and chemical applications. Less irrigation results in less runoff, while less chemical application keeps runoff clean.

C. Proper Septic System Management

Malfunctioning or overflowing septic systems release bacteria and nutrients into the water cycle, contaminating nearby lakes, streams, and estuaries, and ground water. Septic systems must be built in the right place. Trampling ground above the system compacts soil and can cause the systems pipes to collapse. Also, septic systems should be located away from trees because tree roots can crack pipes or obstruct the flow of wastewater through drain lines. Proper septic system management is also important, and a system should be inspected and emptied every 3 to 5 years.

By maintaining water fixtures and by purchasing water-efficient showerheads, faucets, and toilets, households can limit wastewater levels, reducing the likelihood of septic system overflow. Most water conservation technologies provide long-term economic and environmental benefits.

D. Proper Chemical Use, Storage, and Disposal

Household cleaners, grease, oil, plastics, and some food or paper products should not be flushed down drains or washed down the street. Over time chemicals can corrode septic system pipes and might not be completely removed during the filtration process. Chemicals poured down the drain can also interfere with the chemical and biological breakdown of the wastes in the septic tank.

On household lawns and gardens, homeowners can try natural alternatives to chemical fertilizers and pesticides and apply no more than the recommended amounts. Natural predators like insects and bats, composting, and use of native plants can reduce or entirely negate the need for chemicals. Xeriscape can limit chemical applications to lawns and gardens.

If chemicals are needed around the home, they should be stored properly to prevent leaks and access by children. Most cities have designated sites for the proper disposal of used chemicals.

5. Septic System Alternatives

Alternatives to Conventional Septic Systems

When site conditions are not suitable for the standard gravity-flow septic systems, whether from a shallow water table, poor percolation rates, or an inadequate soil layer, then there are several alternative methods for the treatment of effluent coming from a residence.

A. Mound System

The use of an elevated sand mound is one alternative to the conventional gravity flow system. For this method, you must have at least 24 inches of suitable soil and a slope of less than 11% to be able to install a sand mound system. It consists of a septic tank, a dosing chamber and the absorption mound. After the effluent reaches the dosing chamber from the septic tank, it is periodically pumped into the mound in an even fashion, therefore creating even distribution. By incorporating sand filtration and low pressure distribution a soil absorption system is created that produces treated sewage before the effluent even reaches the surrounding subsurface soil. The sand mound system can be costly, ranging from $10,000- $20,000, but the advantage comes from the fact that it needs only about 50% of the area that a gravity-flow system needs.

B. Low Pressure Dosing

A second alternative to the gravity system is the low pressure dosing technique that can be used when there is not enough space to install a standard system. This method uses a pump that evenly distributes the wastewater into trenches, therefore reducing the amount or trench area that would have been needed. The space needed using this system is about 40% less than with the gravity system.

C. Constructed Wetlands

Constructed wetlands are simple, effective wastewater treatment systems specifically designed and built to treat domestic, agricultural, industrial and mining wastewater. Constructed wetlands generally are used by small communities as an alternative to the more expensive conventional wastewater treatment plant, but they also provide an option for homeowners. A constructed wetland is designed and built to resemble a natural wetland. The sides and bottom of an 18-inch deep excavated area are covered with a synthetic or clay liner to prevent leaks. The size of the wetland depends on treatment needs and amount of water to be treated. The area is the filled with rock, gravel, sand, and soil. Aquatic vegetation is planted in order to provide habitat for the microorganisms that actually treat the wastewater. Wastewater from the home flows through the septic tank, where the soilds are removed, and into the wetland where it is distributed evenly.

6. Streambank Erosion Control

Several streambank stabilization techniques will be effective in controlling erosion wherever it is a source of nonpoint pollution. Techniques involving wetland creation and vegetative bank stabilization ("soil bioengineering") will usually be effective at sites with limited exposure to strong currents or wind-generated waves. In other cases, the use of engineering approaches, including armoring structures, may need to be considered. In addition to controlling those sources of sediment input to surface waters that are causing NPS pollution, these techniques can halt the destruction of wetlands and riparian areas located along the shorelines of surface waters. Once these features are protected, they can serve as a filter for surface water runoff from upland areas, or as a sink for nutrients, contaminants, or sediment already present as NPS pollution in surface waters. Stabilization practices involving vegetation or engineering should be properly designed and installed. These techniques should be applied only when there will be no adverse effects to aquatic or riparian river habitat.

Preservation and protection of streambanks can be accomplished through many approaches, but preference is for nonstructural practices, such as soil bioengineering and wetland creation.

Soil bioengineering and other vegetative techniques can be used to restore damaged habitat along streambanks wherever conditions allow. Soil bioengineering is used here to refer to the installation of living plant material as a main structural component in controlling problems of land instability where erosion and sedimentation are occurring. Soil bioengineering largely uses native plants collected in the immediate vicinity of a project site. This ensures that the plant material will be well adapted to site conditions. While a few selected species may be installed for immediate protection, the ultimate goal is for the natural invasion of a diverse plant community to stabilize the site through development of a vegetative cover and a reinforcing root matrix.

Soil bioengineering provides an array of practices that are effective for both prevention and mitigation of NPS problems. This applied technology combines mechanical, biological, and ecological principles to construct protective systems that prevent slope failure and erosion. Adapted types of woody vegetation (shrubs and trees) are initially installed as key structural components, in specified configurations, to offer immediate soil protection and reinforcement. Soil bioengineering systems normally use cut, unrooted plant parts in the form of branches or rooted plants. As the systems establish themselves, resistance to sliding or shear displacement increases in streambanks and upland slopes (Schiechtl, 1980; Gray and Leiser, 1982; Porter, 1992).

Specific soil bioengineering practices are presented in the Appendix and include:

Live Staking.

Live staking involves the insertion and tamping of live, rootable vegetative cuttings into the ground. If correctly prepared and placed, the live stake will root and grow. A system of stakes creates a living root mat that stabilizes the soil by reinforcing and binding soil particles together and by extracting excess soil moisture. Most willow species are ideal for live staking because they root rapidly and begin to dry out a slope soon after installation. This is an appropriate technique for repair of small earth slips and slumps that frequently are wet.

Live Fascines.

Live fascines are long bundles of branch cuttings bound together into sausage-like structures. When cut from appropriate species and properly installed, they will root and immediately begin to stabilize slopes. They should be placed in shallow contour trenches on dry slopes and at an angle on wet slopes to reduce erosion and shallow face sliding. This system, installed by a trained crew, does not cause much site disturbance.

Brushlayering.

Brushlayering consists of placing live branch cuttings in small benches excavated into the slope. The width of the benches can range from 2 to 3 feet. The portions of the brush that protrude from the slope face assist in retarding runoff and reducing surface erosion. Brushlayering is somewhat similar to live fascine systems because both involve the cutting and placement of live branch cuttings on slopes. The two techniques differ principally in the orientation of the branches and the depth to which they are placed in the slope. In brushlayering, the cuttings are oriented more or less perpendicular to the slope contour. In live fascine systems, the cuttings are oriented more or less parallel to the slope contour. The perpendicular orientation is more effective from the point of view of earth reinforcement and mass stability of the slope.

Brush Mattressing.

Brush mattressing is commonly used in Europe for streambank protection. It involves digging a slight depression on the bank and creating a mat or mattress from woven wire or single strands of wire and live, freshly cut branches from sprouting trees or shrubs. Branches up to 2.5 inches in diameter are normally cut 3 to 10 feet long and laid in criss-cross layers with the butts in alternating directions to create a uniform mattress with few voids. The mattress is then covered with wire secured with wooden stakes up to 3 feet long. It is then covered with soil and watered repeatedly to fill voids with soil and facilitate sprouting; however, some branches should be left partially exposed on the surface. The structure may require protection from undercutting by placement of stones or burial of the lower edge. Brush mattresses are generally resistant to waves and currents and provide protection from the digging out of plants by animals. Disadvantages include possible burial with sediment in some situations and difficulty in making later plantings through the mattress.

Branchpacking.

Branchpacking consists of alternating layers of live branch cuttings and compacted backfill to repair small localized slumps and holes in slopes. Live branch cuttings may range from 1/2 inch to 2 inches in diameter. They should be long enough to touch the undisturbed soil at the back of the trench and extend slightly outward from the rebuilt slope face. As plant tops begin to grow, the branchpacking system becomes increasingly effective in retarding runoff and reducing surface erosion. Trapped sediment refills the localized slumps or holes, while roots spread throughout the backfill and surrounding earth to form a unified mass.

Joint Planting.

Joint planting (or vegetated riprap) involves tamping live cuttings of rootable plant material into soil between the joints or open spaces in rocks that have previously been placed on a slope. Alternatively, the cuttings can be tamped into place at the same time that rock is being placed on the slope face.

Live Cribwalls.

A live cribwall consists of a hollow, box-like interlocking arrangement of untreated log or timber members. The structure is filled with suitable backfill material and layers of live branch cuttings, which root inside the crib structure and extend into the slope. Once the live cuttings root and become established, the subsequent vegetation gradually takes over the structural functions of the wood members.

These techniques have been used extensively in Europe for streambank and shoreline protection and for slope stabilization. They have been practiced in the United States only to a limited extent primarily because other engineering options, such as the use of riprap, have been more commonly accepted practices. With the costs of labor, materials, and energy rapidly rising in the last two decades, however, less costly alternatives of stabilization are being pursued as alternatives to engineering structures for controlling erosion of streambanks and shorelines. Additionally, bioengineering has the advantage of providing food, cover, and instream and riparian habitat for fish and wildlife and results in a more aesthetically appealing environment than traditional engineering approaches. Local agencies such as the USDA Soil Conservation Service and Extension Service can be a useful source of information on appropriate native plant species that can be considered for use in bioengineering projects.

A revetment is another type of vertical protective structure used for streambank protection. One revetment design contains several layers of randomly shaped and randomly placed stones, protected with several layers of selected armor units or quarry stone. The armor units in the cover layer should be placed in an orderly manner to obtain good wedging and interlocking between individual stones. The cover layer may also be constructed of specially shaped concrete units.

Sometimes gabions (stone-filled wire baskets) or interlocking blocks of precast concrete are used in the construction of revetments. In addition to the surface layer of armor stone, gabions, or rigid blocks, successful revetment designs also include an underlying layer composed of either geotextile filter fabric and gravel or a crushed stone filter and bedding layer. This lower layer functions to redistribute hydrostatic uplift pressure caused by wave action in the foundation substrate.

Precast cellular blocks, with openings to provide drainage and to allow vegetation to grow through the blocks, can be used in the construction of revetments to stabilize banks. Vegetation roots add additional strength to the bank. In situations where erosion can occur under the blocks, fabric filters can be used to prevent the erosion. Technical assistance should be obtained to properly match the filter and soil characteristics. Typically blocks are hand placed when mechanical access to the bank is limited or costs need to be minimized. Cellular block revetments have the additional benefit of being flexible to conform to minor changes in the bank shape.

7. Wetland Management

Nonpoint source pollution has been identified at the Nation's leading source of surface water and ground water quality impairment. When properly managed, wetlands can help prevent NPS pollution from degrading water quality across the nation and at the local level within the Indian Creek watershed.

Properly managed wetlands can intercept runoff and transform and store NPS pollutants like sediment, nutrients, and certain heavy metal s without being degraded. In addition, wetlands vegetation can keep stream channels intact by slowing runoff and by evenly distributing the energy in runoff. Wetlands vegetation also regulates stream temperature by providing streamside shading. Mr. Jerry Lish of the Lawrence County NRCS reports that significant efforts have gone into developing wetlands along the west side of Indian Creek south of Silverville. These wetlands can be effective tools to control runoff and protect Indian Creek from NPS pollution.

Improper development or excessive pollutant loads can damage wetlands. The degraded wetlands can then no longer provide water quality benefits and the wetlands themselves can become significant sources of NPS pollution. Excessive amounts of decaying wetlands vegetation, for example, can increase biochemical oxygen demand, making habitat unsuitable for fish and other aquatic life. Degraded wetlands also release stored nutrients and other chemicals into surface water and ground water.

The Environmental Protection Agency recommends three management strategies to maintain the water quality benefits provided by wetlands:

- Preservation
- Restoration, and
- Construction of engineered systems that prevent runoff before it reaches receiving waters and wetlands.

A. Wetland Preservation

The first strategy protects the full range of wetlands functions by discouraging development activity. At the same time, this strategy encourages proper management of upstream watershed activities, such as agriculture, forestry, and residential development. Several programs administered by federal and state agencies protect wetlands by either controlling development activities that would affect wetlands or providing financial assistance to people who wish to protect them. In addition, nongovernmental groups that purchase wetlands for conservation purposes, such as The Nature Conservancy, The Trust for Public Land, and local land trusts, are playing an increasingly important role in protecting water quality.

B. Wetland Restoration

The second strategy promotes the restoration of degraded wetlands and riparian zones with NPS pollution control potential. Riparian zones are the vegetated ecosystems along Indian Creek through which energy, materials, and water pass. Riparian areas characteristically have high water-tables and are subject to periodic flooding and influence from the adjacent stream. They encompass wetlands and uplands, or some combination to these two landforms.

Restoration activities should recreate the full range of preexisting wetland functions. That means replanting degraded wetlands with native plant species and, depending on the location and degree of degradation, using structural devices to control water flows. Restoration projects factor in ecological principles, such as habitat diversity and the connections between different aquatic and riparian habitat types, which distinguish these kinds of projects from wetlands that are constructed for runoff pretreatment.

C. Engineered Systems

The third strategy promotes the use of engineered vegetated treatment systems. These systems are especially effective at removing suspended solids and sediment from NPS pollution before the runoff reaches natural wetlands.

One type of vegetated treatment system, the vegetated filter strip, is a swath of land planted with grasses and trees that intercepts uniform sheet flow or runoff, before the runoff reaches wetlands. Filter strips are most effective at sediment removal, with removal rates usually greater than 70%. Constructed wetlands, another type of vegetated treatment system, are typically engineered complexes of water, plants, and animal life that simulate naturally occurring wetlands. Studies indicate the constructed wetlands can achieve sediment removal rates greater than 90 percent. Like filter strips, constructed wetlands offer an alternative to other systems that are more structural in design.

Healthy wetlands benefit fish, wildlife, and humans because they protect many natural resources, only one of which is clean water. Unfortunately, 59% of the wetlands in the Indian Creek watershed were lost in the last 200 years, and undisturbed wetlands still face threats from development. Wetlands protection must be considered to help prevent NPS pollution from further degrading the water quality of Indian Creek and to protect many other natural resources.

VIII. RECOMMENDATIONS

The intent of this project is to describe conditions and trends in Indian Creek and its watershed and to identify potential water quality problems in subwatersheds. This assessment is to provide guidance for future management and land treatment project selection and to predict the impacts of those projects to Indian Creek. The purpose then of this diagnostic study then is to:

- Describe conditions and trends in Indian Creek and the subwatersheds.
- Identify potential nonpoint source water quality problems
- Propose specific direction for future work
- Predict and assess success factors for future work.

The recommendations for enhancing the water quality of Indian Creek center on:

- Reducing the generation of nonpoint sources of pollutants, particularly nutrients and sediment from the watershed.
- Reducing the delivery of nonpoint sources of pollutants to Indian Creek, its tributaries, and the East Fork White River.
- Controlling streambank erosion of Indian Creek and its tributaries.

The Biomonitoring and Habitat Assessment group concluded that the Indian Creek's lowered water quality may be a result of agricultural practices and overall lack of watershed management. The group uncovered some disturbing aspects that warrant vigilance and further study by those wanting to preserve the habitat quality of Indian Creek.

First, the presence of elevated chironomids (midge larvae) and abundant algae growth led the group to conclude that nutrients are elevated. The sources of these nutrients are suspected to be faulty septic systems and nonpoint sources especially livestock production near the streams and access directly to the streams in certain areas. Using farming methods that rely on less fertilizer and pesticides would serve to partially alleviate this problem.

Ten sampling points were selected at mouths of significant subwatersheds and within Indian Creek proper. These points were selected by the consultant in concert with Natural Resources personnel at the State and Federal level (including Lake and River Enhancement Program personnel and local Soil and Water Conservation District personnel. Table V-1 summarizes the significant features of each of the sampling locations. Sample location #8 in Popcorn Creek was selected to be representative of a stream being impacted by direct livestock access to the creek. The table notes that other sampling locations were also used to represent the impact of livestock access. However Popcorn Creek, due in part to its proximity to county roads paralleling the stream, was regarded as a highly visible stream where livestock access was easily documented. Popcorn Creek is of interest also because livestock access to the stream appears to be the predominant contributing factor within that watershed. Other sampling locations such as #5 in Indian Creek, # 6 in Spring Creek, and #9 in Little Indian Creek also were observed to have areas allowing livestock access to the stream however these streams generally had other potential areas of concern when being considered as a sampling location. Livestock access to significant streams was observed to be common practice through out the watershed and is not a management practice unique to Popcorn Creek.

Samples collected from Popcorn Creek had parameters that confirmed the presence of a degraded water quality believed to be directly attributable to livestock access to the stream. Samples had low levels of dissolved oxygen, elevated conductivity readings, and elevated levels of Ammonia N, Total N (TKN), and Total P. These results are considered justification for regarding livestock exclusion from the streams in the watershed as a priority for minimizing the continued degradation of the water quality to Indian Creek. Access of cattle to the stream's ecosystem should be discouraged. Based on the observations of the apparent management regimes of cattle operations along the stream ecosystems, those subwatersheds with the highest concentrations of cattle operations should be focused on. The proportions of land uses identified by subwatershed and presented in Figures IV-13 through IV-18 suggest that the Popcorn Creek, Spring Creek, and Little Indian Creek subwatersheds should be regarded as priority areas for promoting livestock exclusion and grazing management.

Next, even though conservation tillage methods are likely increasing in the area, the silt and topsoil washed into the stream by heavy rainfall events is still coating rocks and filling the pools. Soil conservation efforts including conservation tillage and addition of buffer strips should be intensified to prevent silt from entering the stream. These grass buffers would filter nutrients before they reach the water.

Thirdly, the development of additional wetlands to capture agricultural fertilizer runoff is a possible solution. Evaluation of ponds and drainage fields at livestock farms should be undertaken to further reduce the nutrient and waste inputs to the stream.

Streambank erosion is a wide spread problem in Indian Creek proper and especially in tributaries of Indian Creek. Many of these areas appear to be related to livestock access to streams although not all areas. Most noticeable were streambank failure areas along segments of Popcorn Creek and Spring Creek in Lawrence County and Town Branch in Greene County. Other areas of concern were observed along Sulphur Creek and Little Sulphur Creek in Martin County. Given the length of Indian Creek and just the named tributaries, there are more problem areas along reaches of all the streams such that it is not feasible to specifically identify each one.

Many of the streambank erosion circumstances are aggravated by livestock access and will stabilize if livestock is excluded from the stream. For other cases, there are numerous techniques involving structural and non-structural methods. The "willow post: technique is particularly effective on steep slopes and is relatively inexpensive. However, the resulting dense vegetation that develops can restrict stream access. Re-grading and re-vegetating is recommended on streambanks that are only 3-4 feet high. In many areas, simply leaving streambanks vegetated rather than cutting off the timber will help stabilize and prevent erosion.

Because most of the eroded streambanks are on private land, lack of incentive and financial ability on the landowner's part may limit implementation. Cost-sharing assistance may be available through the Lake and River Enhancement Program. The Program offers technical and financial assistance for streambank erosion control through design and construction projects and watershed land treatment projects.

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APPENDIX

APPENDIX A

Water Quality Field Data

Indian Creek
Water Quality

Indian Creek Field Data						
Station	Location	pH	Conductivity (mS/m)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Temp. (C)
1	Opossum Ck	7.98	0.443	65	7.05	17
2	Sulphur Ck.	8.32	0.464	98	4.54	14
3FB	Indian Ck.	7.83	0.001	8	4.48	20
3	Indian Ck.	8.37	0.397	44	3.23	18
4	Padanaram	8.29	0.314	204	4.3	18
5	Indian Ck.	8.3	0.396	34	3.5	18
6	Spring Ck.	8.84	0.399	24	4.42	17
7	Town Br.	8.82	0.268	179	5.26	16
8	Popcorn Ck.	8.75	0.555	153	1.53	17
9	Lil Indian Ck.	8.7	0.241	61	4.9	16
10	Indian Ck.	8.94	0.314	52	5.75	16

APPENDIX B

Water Quality Laboratory Data

Belmonte Park Environmental Laboratories

DONAN ENGINEERING
4342 N HWY 231
JASPER IN 47546

Attn: ED KNUST
Invoice Number:

Order #: 98-10-373
Date: 10/19/98 08:29
Work ID: INDIAN CREEK 1 - 10
Date Received: 10/08/98
Date Completed: 10/16/98
Client Code: DONAN_1

SAMPLE IDENTIFICATION

Sample Number	Sample Description	
01	INDIAN CREEK 1	10/07/98
02	INDIAN CREEK 1	10/07/98
03	INDIAN CREEK 1	10/07/98
04	INDIAN CREEK 1	10/07/98
05	INDIAN CREEK 2	10/07/98
06	INDIAN CREEK 2	10/07/98
07	INDIAN CREEK 2	10/07/98
08	INDIAN CREEK 2	10/07/98
09	INDIAN CREEK 3	10/07/98
10	INDIAN CREEK 3	10/07/98
11	INDIAN CREEK 3	10/07/98
12	INDIAN CREEK 3	10/07/98
13	INDIAN CREEK 3FR	10/07/98
14	INDIAN CREEK 3FR	10/07/98
15	INDIAN CREEK 3FR	10/07/98
16	INDIAN CREEK 3FR	10/07/98
17	INDIAN CREEK 4	10/07/98
18	INDIAN CREEK 4	10/07/98
19	INDIAN CREEK 4	10/07/98
20	INDIAN CREEK 4	10/07/98
21	INDIAN CREEK 5	10/07/98
22	INDIAN CREEK 5	10/07/98
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41	INDIAN CREEK 10	10/07/98
42	INDIAN CREEK 10	10/07/98
43	INDIAN CREEK 10	10/07/98
44	INDIAN CREEK 10	10/07/98

Enclosed are results of specified samples submitted for analyses. If there are any questions, please contact Matt Lake. Our Ohio EPA Certification numbers are 836 & 837. Any result of "BDL" indicates "BELOW DETECTION LIMIT".

M Lake

Certified By
MATT LAKE

Belmonte Park Environmental Laboratories

Order # 98-10-373
10/19/98 08:29

TEST RESULTS BY SAMPLE

Sample: 01A INDIAN CREEK 1 10/07/98 Collected: 10/07/98 Category: AQUEOUS

Test Description		Result	Detection Limit	Units	Analyzed	By
NITRATE NITROGEN		0.83	0.2	mg/L	10/13/98	TC
NITRITE NITROGEN		BDL	0.2	mg/L	10/13/98	TC

Sample: 02A INDIAN CREEK 1 10/07/98 Collected: 10/07/98 Category: AQUEOUS

Test Description		Result	Detection Limit	Units	Analyzed	By
AMMONIA N,	EPA 350.2	BDL	0.5	mg/L	10/14/98	TC
PHOSPHORUS,	EPA 365.1	0.13	0.1	mg/L	10/16/98	LG
TKN,	EPA 351.3	BDL	0.5	mg/L	10/13/98	TC

Sample: 03A INDIAN CREEK 1 10/07/98 Collected: 10/07/98 Category: AQUEOUS

Test Description		Result	Detection Limit	Units	Analyzed	By
o-PHOSPHATE,	EPA 365.1	BDL	0.1	mg/L	10/16/98	LG

Sample: 04A INDIAN CREEK 1 10/07/98 Collected: 10/07/98 Category: AQUEOUS

Test Description		Result	Detection Limit	Units	Analyzed	By
SUSPENDED SOLIDS,	EPA 160.2	17	5	mg/L	10/13/98	TC

Sample: 05A INDIAN CREEK 2 10/07/98 Collected: 10/07/98 Category: AQUEOUS

Test Description		Result	Detection Limit	Units	Analyzed	By
NITRATE NITROGEN		0.29	0.2	mg/L	10/13/98	TC
NITRITE NITROGEN		BDL	0.2	mg/L	10/13/98	TC

Sample: 06A INDIAN CREEK 2 10/07/98 Collected: 10/07/98 Category: AQUEOUS

Test Description		Result	Detection Limit	Units	Analyzed	By
AMMONIA N,	EPA 350.2	BDL	0.5	mg/L	10/14/98	TC
PHOSPHORUS,	EPA 365.1	0.14	0.1	mg/L	10/16/98	LG
TKN,	EPA 351.3	0.7	0.5	mg/L	10/13/98	TC

11 East Main Street Dayton, Ohio 45426 (937) 837-3744

Belmonte Park Environmental Laboratories

Order # 98-10-373
10/19/98 08:29

TEST RESULTS BY SAMPLE

Sample: 07A INDIAN CREEK 2 10/07/98 Collected: 10/07/98 Category: AQUEOUS

Test Description		Result	Detection Limit	Units	Analyzed	By
o-PHOSPHATE,	EPA 365.1	BDL	0.1	mg/L	10/16/98	LG

Sample: 08A INDIAN CREEK 2 10/07/98 Collected: 10/07/98 Category: AQUEOUS

Test Description		Result	Detection Limit	Units	Analyzed	By
SUSPENDED SOLIDS,	EPA 160.2	34	5	mg/L	10/13/98	TC

Sample: 09A INDIAN CREEK 3 10/07/98 Collected: 10/07/98 Category: AQUEOUS

Test Description		Result	Detection Limit	Units	Analyzed	By
NITRATE NITROGEN		0.26	0.2	mg/L	10/13/98	TC
NITRITE NITROGEN		BDL	0.2	mg/L	10/13/98	TC

Sample: 10A INDIAN CREEK 3 10/07/98 Collected: 10/07/98 Category: AQUEOUS

Test Description		Result	Detection Limit	Units	Analyzed	By
AMMONIA N,	EPA 350.2	BDL	0.5	mg/L	10/14/98	TC
PHOSPHORUS,	EPA 365.1	0.10	0.1	mg/L	10/16/98	LG
TKN,	EPA 351.3	BDL	0.5	mg/L	10/13/98	TC

Sample: 11A INDIAN CREEK 3 10/07/98 Collected: 10/07/98 Category: AQUEOUS

Test Description		Result	Detection Limit	Units	Analyzed	By
o-PHOSPHATE,	EPA 365.1	BDL	0.1	mg/L	10/16/98	LG

Sample: 12A INDIAN CREEK 3 10/07/98 Collected: 10/07/98 Category: AQUEOUS

Test Description		Result	Detection Limit	Units	Analyzed	By
SUSPENDED SOLIDS,	EPA 160.2	12	5	mg/L	10/13/98	TC

Sample: 13A INDIAN CREEK 3FR 10/07/98 Collected: 10/07/98 Category: AQUEOUS

Test Description		Result	Detection Limit	Units	Analyzed	By
NITRATE NITROGEN		BDL	0.2	mg/L	10/13/98	TC

Belmonte Park Environmental Laboratories

Order # 98-10-373
10/19/98 08:29

TEST RESULTS BY SAMPLE

Test Description		Result	Detection Limit	Units	Analyzed	By
NITRITE NITROGEN		BDL	0.2	mg/L	10/13/98	TC

Sample: 14A INDIAN CREEK 3FR 10/07/98 Collected: 10/07/98 Category: AQUEOUS

Test Description		Result	Detection Limit	Units	Analyzed	By
AMMONIA N,	EPA 350.2	BDL	0.5	mg/L	10/14/98	TC
PHOSPHORUS,	EPA 365.1	BDL	0.1	mg/L	10/16/98	LG
TKN,	EPA 351.3	BDL	0.5	mg/L	10/13/98	TC

Sample: 15A INDIAN CREEK 3FR 10/07/98 Collected: 10/07/98 Category: AQUEOUS

Test Description		Result	Detection Limit	Units	Analyzed	By
o-PHOSPHATE,	EPA 365.1	BDL	0.1	mg/L	10/16/98	LG

Sample: 16A INDIAN CREEK 3FR 10/07/98 Collected: 10/07/98 Category: AQUEOUS

Test Description		Result	Detection Limit	Units	Analyzed	By
SUSPENDED SOLIDS,	EPA 160.2	BDL	5	mg/L	10/13/98	TC

Sample: 17A INDIAN CREEK 4 10/07/98 Collected: 10/07/98 Category: AQUEOUS

Test Description		Result	Detection Limit	Units	Analyzed	By
NITRATE NITROGEN		BDL	0.2	mg/L	10/13/98	TC
NITRITE NITROGEN		BDL	0.2	mg/L	10/13/98	TC

Sample: 18A INDIAN CREEK 4 10/07/98 Collected: 10/07/98 Category: AQUEOUS

Test Description		Result	Detection Limit	Units	Analyzed	By
AMMONIA N,	EPA 350.2	BDL	0.5	mg/L	10/14/98	TC
PHOSPHORUS,	EPA 365.1	0.13	0.1	mg/L	10/16/98	LG
TKN,	EPA 351.3	0.5	0.5	mg/L	10/13/98	TC

Sample: 19A INDIAN CREEK 4 10/07/98 Collected: 10/07/98 Category: AQUEOUS

Test Description		Result	Detection Limit	Units	Analyzed	By
o-PHOSPHATE,	EPA 365.1	BDL	0.1	mg/L	10/16/98	LG

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TEST RESULTS BY SAMPLE

Sample: 20A INDIAN CREEK 4 10/07/98 Collected: 10/07/98 Category: AQUEOUS

Test Description	Result	Detection Limit	Units	Analyzed	By
SUSPENDED SOLIDS,EPA 160.2	56	5	mg/L	10/13/98	TC

Sample: 21A INDIAN CREEK 5 10/07/98 Collected: 10/07/98 Category: AQUEOUS

Test Description	Result	Detection Limit	Units	Analyzed	By
NITRATE NITROGEN	BDL	0.2	mg/L	10/13/98	TC
NITRITE NITROGEN	BDL	0.2	mg/L	10/13/98	TC

Sample: 22A INDIAN CREEK 5 10/07/98 Collected: 10/07/98 Category: AQUEOUS

Test Description	Result	Detection Limit	Units	Analyzed	By
AMMONIA N, EPA 350.2	BDL	0.5	mg/L	10/14/98	TC
PHOSPHORUS, EPA 365.1	0.10	0.1	mg/L	10/16/98	LG
TKN, EPA 351.3	BDL	0.5	mg/L	10/13/98	TC

Sample: 23A INDIAN CREEK 5 10/07/98 Collected: 10/07/98 Category: AQUEOUS

Test Description	Result	Detection Limit	Units	Analyzed	By
o-PHOSPHATE, EPA 365.1	BDL	0.1	mg/L	10/16/98	LG

Sample: 24A INDIAN CREEK 5 10/07/98 Collected: 10/07/98 Category: AQUEOUS

Test Description	Result	Detection Limit	Units	Analyzed	By
SUSPENDED SOLIDS,EPA 160.2	11	5	mg/L	10/13/98	TC

Sample: 25A INDIAN CREEK 6 10/07/98 Collected: 10/07/98 Category: AQUEOUS

Test Description	Result	Detection Limit	Units	Analyzed	By
NITRATE NITROGEN	0.51	0.2	mg/L	10/13/98	TC
NITRITE NITROGEN	BDL	0.2	mg/L	10/13/98	TC

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TEST RESULTS BY SAMPLE

Sample: 26A INDIAN CREEK 6 10/07/98 Collected: 10/07/98 Category: AQUEOUS

Test Description		Result	Detection Limit	Units	Analyzed	By
AMMONIA N,	EPA 350.2	BDL	0.5	mg/L	10/14/98	TC
PHOSPHORUS,	EPA 365.1	0.15	0.1	mg/L	10/16/98	LG
TKN,	EPA 351.3	BDL	0.5	mg/L	10/13/98	TC

Sample: 27A INDIAN CREEK 6 10/07/98 Collected: 10/07/98 Category: AQUEOUS

Test Description		Result	Detection Limit	Units	Analyzed	By
o-PHOSPHATE,	EPA 365.1	BDL	0.1	mg/L	10/16/98	LG

Sample: 28A INDIAN CREEK 6 10/07/98 Collected: 10/07/98 Category: AQUEOUS

Test Description	Result	Detection Limit	Units	Analyzed	By
SUSPENDED SOLIDS,EPA 160.2	BDL	5	mg/L	10/13/98	TC

Sample: 29A INDIAN CREEK 7 10/07/98 Collected: 10/07/98 Category: AQUEOUS

Test Description	Result	Detection Limit	Units	Analyzed	By
NITRATE NITROGEN	1.4	0.2	mg/L	10/13/98	TC
NITRITE NITROGEN	BDL	0.2	mg/L	10/13/98	TC

Sample: 30A INDIAN CREEK 7 10/07/98 Collected: 10/07/98 Category: AQUEOUS

Test Description		Result	Detection Limit	Units	Analyzed	By
AMMONIA N,	EPA 350.2	BDL	0.5	mg/L	10/14/98	TC
PHOSPHORUS,	EPA 365.1	0.21	0.1	mg/L	10/16/98	LG
TKN,	EPA 351.3	0.5	0.5	mg/L	10/13/98	TC

Sample: 31A INDIAN CREEK 7 10/07/98 Collected: 10/07/98 Category: AQUEOUS

Test Description		Result	Detection Limit	Units	Analyzed	By
o-PHOSPHATE,	EPA 365.1	BDL	0.1	mg/L	10/16/98	LG

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TEST RESULTS BY SAMPLE

Sample: 32A INDIAN CREEK 7 10/07/98 Collected: 10/07/98 Category: AQUEOUS

Test Description	Result	Detection Limit	Units	Analyzed	By
SUSPENDED SOLIDS,EPA 160.2	59	5	mg/L	10/13/98	TC

Sample: 33A INDIAN CREEK 8 10/07/98 Collected: 10/07/98 Category: AQUEOUS

Test Description	Result	Detection Limit	Units	Analyzed	By
NITRATE NITROGEN	BDL	0.2	mg/L	10/13/98	TC
NITRITE NITROGEN	BDL	0.2	mg/L	10/13/98	TC

Sample: 34A INDIAN CREEK 8 10/07/98 Collected: 10/07/98 Category: AQUEOUS

Test Description	Result	Detection Limit	Units	Analyzed	By
AMMONIA N, EPA 350.2	11.7	0.5	mg/L	10/15/98	TC
PHOSPHORUS, EPA 365.1	0.71	0.1	mg/L	10/16/98	LG
TKN, EPA 351.3	15.8	0.5	mg/L	10/14/98	TC

Sample: 35A INDIAN CREEK 8 10/07/98 Collected: 10/07/98 Category: AQUEOUS

Test Description	Result	Detection Limit	Units	Analyzed	By
o-PHOSPHATE, EPA 365.1	BDL	0.1	mg/L	10/16/98	LG

Sample: 36A INDIAN CREEK 8 10/07/98 Collected: 10/07/98 Category: AQUEOUS

Test Description	Result	Detection Limit	Units	Analyzed	By
SUSPENDED SOLIDS,EPA 160.2	33	5	mg/L	10/13/98	TC

Sample: 37A INDIAN CREEK 9 10/07/98 Collected: 10/07/98 Category: AQUEOUS

Test Description	Result	Detection Limit	Units	Analyzed	By
NITRATE NITROGEN	0.74	0.2	mg/L	10/13/98	TC
NITRITE NITROGEN	BDL	0.2	mg/L	10/13/98	TC

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TEST RESULTS BY SAMPLE

Sample: 38A INDIAN CREEK 9 10/07/98 Collected: 10/07/98 Category: AQUEOUS

Test Description		Result	Detection Limit	Units	Analyzed	By
AMMONIA N,	EPA 350.2	BDL	0.5	mg/L	10/14/98	TC
PHOSPHORUS,	EPA 365.1	0.33	0.1	mg/L	10/16/98	LG
TKN,	EPA 351.3	1.1	0.5	mg/L	10/14/98	TC

Sample: 39A INDIAN CREEK 9 10/07/98 Collected: 10/07/98 Category: AQUEOUS

Test Description		Result	Detection Limit	Units	Analyzed	By
o-PHOSPHATE,	EPA 365.1	0.19	0.1	mg/L	10/16/98	LG

Sample: 40A INDIAN CREEK 9 10/07/98 Collected: 10/07/98 Category: AQUEOUS

Test Description		Result	Detection Limit	Units	Analyzed	By
SUSPENDED SOLIDS,	EPA 160.2	9	5	mg/L	10/13/98	TC

Sample: 41A INDIAN CREEK 10 10/07/98 Collected: 10/07/98 Category: AQUEOUS

Test Description		Result	Detection Limit	Units	Analyzed	By
NITRATE NITROGEN		1.4	0.2	mg/L	10/13/98	TC
NITRITE NITROGEN		BDL	0.2	mg/L	10/13/98	TC

Sample: 42A INDIAN CREEK 10 10/07/98 Collected: 10/07/98 Category: AQUEOUS

Test Description		Result	Detection Limit	Units	Analyzed	By
AMMONIA N,	EPA 350.2	BDL	0.5	mg/L	10/14/98	TC
PHOSPHORUS,	EPA 365.1	0.27	0.1	mg/L	10/16/98	LG
TKN,	EPA 351.3	BDL	0.5	mg/L	10/14/98	TC

Sample: 43A INDIAN CREEK 10 10/07/98 Collected: 10/07/98 Category: AQUEOUS

Test Description		Result	Detection Limit	Units	Analyzed	By
o-PHOSPHATE,	EPA 365.1	0.14	0.1	mg/L	10/16/98	LG

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TEST RESULTS BY SAMPLE

Sample: 44A INDIAN CREEK 10 10/07/98 Collected: 10/07/98 Category: AQUEOUS

Test Description	Result	Detection Limit	Units	Analyzed	By
SUSPENDED SOLIDS,EPA 160.2	13	5	mg/L	10/13/98	TC

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Address: 4342 N Hwy 231
City, State, Zip: Jasper IN 47546

REPORT RESULTS TO
Name: Same
Title:
Company:
Dept.:
Mailing Address:
City, State, Zip:
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Date Results Req.:
Rush Charges Authorized? ☐ Yes ☒ No
Phone / Fax Results ☐ ☐
Check Regulatory Type: ☐ NPDES ☐ UST ☐ SDWA ☐ FDA/USDA ☐ RCRA ☐ other ☐ Collected in State of IN

Special Instructions:

ANALYSIS REQUESTED
(Enter an 'X' in the box below to indicate request)

CLIENT SAMPLE IDENTIFICATION	DATE SAMPLED	TIME	COMP	GRAB	SAMPLE TYPE (MATRIX)	Number of Containers	Nitrate/Nitrite	TKN	NH3	Total Phos	SRP	TSS				LAB ONLY
Indian Creek 1	10/7/98			X	Water	4	X	X	X	X	X	X				
2						4										
3						4										
3 FB						4										
4						4										
5						4										
6						4										
7						4										
8						4										
9						4										
10						4										

CHAIN OF CUSTODY (if required)
Relinquished by: Ed Knust — Date/Time 10/7/98 1600 — Received by: — Date/Time
Relinquished by: — Date/Time — Received at lab by: [illegible] — Date/Time 10-8 9:15
Method of Shipment: Fed-X
Comments: [illegible]

Authorized by: Ed Knust — Date 10/7/98
(Client Signature Must Accompany Request)

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APPENDIX C

QHEI Sheets

STREAM: Opossum Creek   RIVER MILE: Station 1   DATE:9/16/98 QHEI SCORE **28.5**

1) SUBSTRATE: (Check ONLY Two Substrate Type Boxes: Check all types present) SUBSTRATE SCORE 5

TYPE	POOL	RIFFLE	SUBSTRATE ORIGIN (ALL)	SILT COVER (check one)
BLDER/SLAB(10)			LIMESTONE(1)	***SILT HEAVY(-2)***
BOULDER (9)			***TILLS (1)***	SILT-NORM. (0)
COBBLE(8)			SHALE (-1)	SLT-MOD.(-1)
GRAVEL(7)			COAL FINES (-2)	SLT-FREE (1)
SAND (6)	X	X	HARDPAN (0)	Extent of Embeddedness
BEDROCK(5)			***RIP/RAP(0)***	(check one)
HARDPAN (4)			SANDSTONE(0)	***EXTENSIVE (-2)***
DETRITUS (3)	X	X		MODERATE (-1)
MUCK/SILT (2)	X	X		LOW (0)
ARTIFIC. (0)				NONE (1)

TOTAL NUMBER OF SUBSTRATE TYPES: >4 (2) ***<4 (0)***

NOTE: (ignore sludge that originates from point sources: score is based on natural substrates)

COMMENTS: Altered drainage way in agricultural area.

2) INSTREAM COVER   COVER SCORE 2

TYPE (Check all that Apply)	AMOUNT (Check only one or Check 2 and AVERAGE)
UNDERCUT BANKS (1)	
OVERHANGING VEGETATION (1)	EXTENSIVE >75% 11
DEEP POOLS (2)	MODERATE 25-75% (7)
ROOTWADS (1)	SPARSE 5-25% (3)
SHALLOWS (IN SLOW WATER)(1)	***NEARLY ABSENT <5% (1)***
OXBOWS (1)	
AQUATIC MACROPHYTES(1)	
LOGS OR WOODY DEBRIS(1)	
BOULDERS (1)	

COMMENTS:

3) CHANNEL MORPHOLOGY: (Check ONLY ONE per Category or Check 2 and AVERAGE) CHANNEL SCORE 9

SINUOSITY	DEVELOPMENT	CHANNELIZATION	STABILITY	MODIFICATION/OTHER--NONE	
HIGH (4)	EXCELLENT (7)	NONE (6)	HIGH (3)	IMPOUND	SNAGGING
MODERATE (3)	GOOD (S)	***RECOVERED (4)***	***MODERATE (2)***	ISLAND	RELOCATION
LOW (2)	FAIR (3)	RECOVERING (3)	LOW (1)	CANOPY REMOVAL	LEVEED
NONE (1)	***POOR (1)***	RECENT OR NO		***DREDGING***	BANK SHAPING
		RECOVERY (1)		***ONE SIDE CHANNEL MODIFICATION***	

COMMENTS: Tile drains and new tile drains

4) RIPARIAN ZONE AND BANK EROSION:(Check ONE box or Ck 2 and AVERAGE/bank) RIPARIAN SCORE 4.5

River Right Looking Downstream

RIPARIAN WIDTH LR (per bank)	EROSION/RUNOFF-FLOODPLAIN QUAL	BANK EROSION LR (per bank
WIDE >150 ft (4)	FOREST, SWAMP (3) LR (per bank)	***NONE OR LITTLE (3) LR***
MODERATE 30-150 ft (3)	SHRUB OR OLD FIELD (2)	MODERATE (2)
NARROW 15-30 ft (2)	***CONSERV. TILLAGE (1)***	HEAVY OR SEVERE (1
VERY NARROW 3-15 ft.(1) LR	FENCED PASTURE (1)	
NONE (O)	RESID, PARK NEW FIELD (1)	
	URBAN OR INDUSTRIAL (0)	
	OPEN PASTURE/ROW CROP (0)	
	MINING/CONSTRUCTION (O)	

COMMENTS: Work on riparian zone downstream. Backhoe and modification observed.

5) POOL/GLIDE AND RIFFLE/RUN QUALITY   POOL SCORE 4

MAX. DEPTH (Check 1)	MORPHOLOGY (Check 1)	POOL/RUN/RIFFLE CURRENT VELOCIT (Check all that Apply)
>4 ft (6)	***POOL WIDTH > RIFFLE WIDTH (2)***	TORRENTIAL (-1) ***SLOW (1)***
2.4-4 ft(4)	POOL WIDTH = RIFFLE WIDTH (1)	EDDIES (1) INTERSTITIAL (-1)
1.2-2.4 ft (2)	POOL WIDTH < RIFFLE WIDTH (O)	FAST (1) INTERMITTENT (-2)
<1.2 ft (1)		MODERATE (1)
<0.6 ft (0) (No Pool=0)		

COMMENTS: We sunk into the pool muck. Pool width was 8'2".   RIFFLE SCORE 0

RIFFLE/RUN DEPTH	RIFFLE/RUN SUBSTRATE	RIFFLE/RUN EMBEDDEDNESS
GENERALLY >4 in. MAX >20 in (4)	STABLE (e.g., Cobble, Boulder)	***EXTENSIVE (-1)***
GENERALLY>4 in. MAX <20 in (3)	MOD.STABLE (e-g., Pea Gravel) (	NONE (2)
GENERALLY 2-4 in (1)	UNSTABLE (Gravel, ***Sand) (0)***	LOW (1)
GENERALLY <2 in (Riffle=0)		MODERATE (0
NO RIFFLE (O)		

COMMENTS: Filamentous algae bloom prevalent.

6) GRADIENT (FEET/MILE): 8.85 %POOL 60 %RIFFLE 30 %RUN 10 GRADIENT SCORE 4

STREAM: Sulphur Creek RIVER MILE: Station 2 DATE: 9/16/98 QHEI SCORE **70**

Indian Springs, Indiana 7.5 minute quadrangle

1) SUBSTRATE: (Check ONLY Two Substrate Type Boxes: Check all types present) SUBSTRATE SCORE 10

TYPE	POOL	RIFFLE	SUBSTRATE ORIGIN (ALL)	SILT COVER (check one)
BLDER/SLAB(10)			LIMESTONE(1)	SILT HEAVY(-2)
BOULDER (9)	X		TILLS (1)	***SILT-NORM. (0)***
COBBLE(8)	X		SHALE (-1)	SLT-MOD.(-1)
GRAVEL(7)		X	COAL FINES (-2)	SLT-FREE (1)
SAND (6)	X	X	HARDPAN (0)	Extent of Embeddedness
BEDROCK(5)			RIP/RAP(0)	(check one)
HARDPAN (4)			***SANDSTONE(0)***	EXTENSIVE (-2)
DETRITUS (3)	X			***MODERATE (-1)***
MUCK/SILT (2)	X	X		LOW (0)
ARTIFIC. (0)				NONE (1)

TOTAL NUMBER OF SUBSTRATE TYPES: ***>4 (2)*** <4 (0)

NOTE: (ignore sludge that originates from point sources: score is based on natural substrates)

COMMENTS: Sandstone rocks; sunk into muck downstream.

2) INSTREAM COVER COVER SCORE 14

TYPE (Check all that Apply)	AMOUNT (Check only one or Check 2 and AVERAGE)
UNDERCUT BANKS (1)	
OVERHANGING VEGETATION (1)	EXTENSIVE >75% 11
DEEP POOLS (2)	***MODERATE 25-75% (7)***
ROOTWADS (1)	SPARSE 5-25% (3)
SHALLOWS (IN SLOW WATER)(1)	NEARLY ABSENT <5% (1)
OXBOWS (1)	
AQUATIC MACROPHYTES(1)	
LOGS OR WOODY DEBRIS(1)	
BOULDERS (1)	

COMMENTS: Area disturbed only by the roads and historical trash dumping.

3) CHANNEL MORPHOLOGY: (Check ONLY ONE per Category or Check 2 and AVERAGE) CHANNEL SCORE 15

SINUOSITY	DEVELOPMENT	CHANNELIZATION	STABILITY	MODIFICATION/OTHER--***NONE***	
HIGH (4)	EXCELLENT (7)	***NONE (6)***	HIGH (3)	IMPOUND	SNAGGING
MODERATE (3)	***GOOD (5)***	RECOVERED (4)	***MODERATE (2)***	ISLAND	RELOCATION
LOW (2)	FAIR (3)	RECOVERING (3)	LOW (1)	CANOPY REMOVAL	LEVEED
NONE (1)	POOR (1)	RECENT OR NO		DREDGING	BANK SHAPING
		RECOVERY (1)		ONE SIDE CHANNEL MODIFICATION	

COMMENTS: Vegetation: sugar maple, sycamore, large beech, birch, ironwood. Understory: smartweed, Cardinal flower, pokeweed, and joe pie weed. Arrowhead also noted.

4) RIPARIAN ZONE AND BANK EROSION: Check ONE box or Ck 2 and average. RIPARIAN SCORE 10

River Right Looking Downstream

RIPARIAN WIDTH LR (per bank)	EROSION/RUNOFF-FLOODPLAIN QUAL	BANK EROSION LR (per bank
WIDE >150 ft (4) LR	***FOREST, SWAMP (3) LR*** (per bank)	***NONE OR LITTLE (3) LR***
MODERATE 30-150 ft (3)	SHRUB OR OLD FIELD (2)	MODERATE (2)
NARROW 15-30 ft (2)	CONSERV. TILLAGE (1)	HEAVY OR SEVERE (1
VERY NARROW 3-15 ft.(1)	FENCED PASTURE (1)	
NONE (0)	RESID, PARK NEW FIELD (1)	
	URBAN OR INDUSTRIAL (0)	
	OPEN PASTURE/ROW CROP (0)	
	MINING/CONSTRUCTION (0)	

COMMENTS: Beaver signs. Very few incidental fish noted. Common striped shiners

5) POOL/GLIDE AND RIFFLE/RUN QUALITY POOL SCORE 8

MAX. DEPTH (Check 1)	MORPHOLOGY (Check 1)	POOL/RUN/RIFFLE CURRENT VELOCITY
>4 ft (6)	***POOL WIDTH > RIFFLE WIDTH (2)***	(Check all that Apply)
2.4-4 ft(4)	POOL WIDTH = RIFFLE WIDTH (1)	TORRENTIAL (-1) ***SLOW (1)***
1.2-2.4 ft (2)	POOL WIDTH < RIFFLE WIDTH (0)	***EDDIES (1)*** INTERSTITIAL (-1)
<1.2 ft (1)		FAST (1) INTERMITTENT (-2)
<0.6 ft (0) (No Pool=0)		***MODERATE (1)***

COMMENTS: Pool was 27'7" wide. RIFFLE SCORE 3

RIFFLE/RUN DEPTH	RIFFLE/RUN SUBSTRATE	RIFFLE/RUN EMBEDDEDNESS
GENERALLY >4 in. MAX >20 in (4)	STABLE (Cobble, Boulder) (2)	EXTENSIVE (-1)
GENERALLY>4 in. MAX <20 in (3)	***MOD.STABLE*** **(Pea Gravel) (1)**	NONE (2)
GENERALLY 2-4 in (1)	UNSTABLE (Gravel, Sand) (0)	***LOW (1)***
GENERALLY <2 in (Riffle=0)		MODERATE (0
NO RIFFLE (0)		

COMMENTS: Only occasional riffles. The riffle studied was 11'6" in length.

6) GRADIENT (FEET/MILE): 3.15 %POOL 60 %RIFFLE 30 %RUN 10 GRADIENT SCORE 4

STREAM: Indian Creek RIVER MILE: Station 3 DATE: 9/16/98 QHEI SCORE **54.5**

1) SUBSTRATE: (Check ONLY Two Substrate Type Boxes: Check all types present) SUBSTRATE SCORE 6

TYPE	POOL	RIFFLE	SUBSTRATE ORIGIN (ALL)	SILT COVER (check one)
BLDER/SLAB(10)	X		***LIMESTONE(1)***	SILT HEAVY(-2)
BOULDER (9)	X		TILLS (1)	SILT-NORM. (0)
COBBLE(8)			SHALE (-1)	***SLT-MOD.(-1)***
GRAVEL(7)		X	COAL FINES (-2)	SLT-FREE (1)
SAND (6)			HARDPAN (0)	Extent of Embeddedness (check one)
BEDROCK(5)		X	RIP/RAP(0)	***EXTENSIVE (-2)***
HARDPAN (4)	X		SANDSTONE(0)	MODERATE (-1)
DETRITUS (3)	X	X		LOW (0)
MUCK/SILT (2)	X	X		NONE (1)
ARTIFIC. (0)				

TOTAL NUMBER OF SUBSTRATE TYPES: ***>4 (2)*** <4 (0)

NOTE: (ignore sludge that originates from point sources: score is based on natural substrates)

COMMENTS: Significant logs/debris creating silt/debris dams. No rapid water in this area.

2) INSTREAM COVER COVER SCORE 11

TYPE (Check all that Apply)	AMOUNT (Check only one or Check 2 and AVERAGE)
UNDERCUT BANKS (1)	
OVERHANGING VEGETATION (1)	EXTENSIVE >75% (11)
DEEP POOLS (2)	***MODERATE 25-75% (7)***
ROOTWADS (1)	SPARSE 5-25% (3)
SHALLOWS (IN SLOW WATER)(1)	NEARLY ABSENT <5% (1)
OXBOWS (1)	
AQUATIC MACROPHYTES(1)	
LOGS OR WOODY DEBRIS(1)	
BOULDERS (1)	

COMMENTS: Low water; rootwads were exposed. Banks were judged to be unstable.

3) CHANNEL MORPHOLOGY: (Check ONLY ONE/Category or Ck 2 and AVERAGE) CHANNEL SCORE 16

SINUOSITY	DEVELOPMENT	CHANNELIZATION	STABILITY	MODIFICATION/OTHER--***NONE***	
HIGH (4)	EXCELLENT (7)	***NONE (6)***	HIGH (3)	IMPOUND	SNAGGING
MODERATE (3)	***GOOD (5)***	RECOVERED (4)	***MODERATE (2)***	ISLAND	RELOCATION
LOW (2)	FAIR (3)	RECOVERING (3)	LOW (1)	CANOPY REMOVAL	LEVEED
NONE (1)	POOR (1)	RECENT OR NO RECOVERY (1)		DREDGING	BANK SHAPING
				ONE SIDE CHANNEL MODIFICATION	

COMMENTS: Looking downstream. Field on right; urban old field/park on left

4) RIPARIAN ZONE AND BANK EROSION: Check ONE box or Ck 2 and average RIPARIAN SCORE 6.5

River Right Looking Downstream

RIPARIAN WIDTH LR (per bank)	EROSION/RUNOFF-FLOODPLAIN QUAL	BANK EROSION LR (per bank
WIDE >150 ft (4) LR	FOREST, SWAMP (3) LR (per bank)	NONE OR LITTLE (3)
MODERATE 30-150 ft (3) LR	***SHRUB OR OLD FIELD (2) L***	***MODERATE (2)***
NARROW 15-30 ft (2)	***CONSERV. TILLAGE (1) L***	HEAVY OR SEVERE (1
VERY NARROW 3-15 ft.(1)	FENCED PASTURE (1)	
NONE (0)	RESID, PARK NEW FIELD (1)	
	URBAN OR INDUSTRIAL (0)	
	OPEN PASTURE/ROW CROP (0) R	
	MINING/CONSTRUCTION (0)	

COMMENTS: Steep bank with large maples; sparse understory beneath trees.

5) POOL/GLIDE AND RIFFLE/RUN QUALITY POOL SCORE 10

MAX. DEPTH (Check 1)	MORPHOLOGY (Check 1)	POOL/RUN/RIFFLE CURRENT VELOCITY (Check all that Apply)
>4 ft (6)	***POOL WIDTH > RIFFLE WIDTH (2)***	TORRENTIAL (-1) ***SLOW (1)***
2.4-4 ft(4)	POOL WIDTH = RIFFLE WIDTH (1)	***EDDIES (1)*** INTERSTITIAL (-1)
1.2-2.4 ft (2)	POOL WIDTH < RIFFLE WIDTH (0)	FAST (1) INTERMITTENT (-2)
<1.2 ft (1)		MODERATE (1)
<0.6 ft (0) (No Pool=0)		

COMMENTS: The pool had a hardpan bottom with some logs on the bottom. RIFFLE SCORE 3

RIFFLE/RUN DEPTH	RIFFLE/RUN SUBSTRATE	RIFFLE/RUN EMBEDDEDNESS
GENERALLY >4"MAX >20" (4)	STABLE (Cobble, Boulder) (2)	***EXTENSIVE (-1)***
GENERALLY>4 in. MAX <20 in (3)	MOD.STABLE (Pea Gravel) (1)	NONE (2)
GENERALLY 2-4 in (1)	***UNSTABLE (Gravel, Sand) (0)***	LOW (1)
GENERALLY <2 in (Riffle=0)	The substrate was mostly silt with some sand.	MODERATE (0)
NO RIFFLE (0)		No riffle. Embeddedness extensive

COMMENTS: Only occasional riffles. The faster water glide area was 35' across. No fish.

6) GRADIENT (FEET/MILE): 0.85 %POOL 98 %RIFFLE %RUN 2 GRADIENT SCORE 2

STREAM: Trib. Of Indiana CK RIVER MILE: Station 4 Padanaram DATE: 9/16/98 QHEI SCORE **58**

1) SUBSTRATE: (Check ONLY Two Substrate Type Boxes: Check all types present) SUBSTRATE SCORE 4

TYPE	POOL	RIFFLE	SUBSTRATE ORIGIN (ALL)	SILT COVER (check one)
BLDER/SLAB(10)	X	X	LIMESTONE(1)	SILT HEAVY(-2)
BOULDER (9)	X Artificial		***TILLS (1)***	SILT-NORM. (0)
COBBLE(8)			SHALE (-1)	***SLT-MOD.(-1)***
GRAVEL(7)	X	X	COAL FINES (-2)	SLT-FREE (1)
SAND (6)			HARDPAN (0)	Extent of Embeddedness
BEDROCK(5)			***RIP/RAP(0)***	(check one)
HARDPAN (4)	X		SANDSTONE(0)	EXTENSIVE (-2)
DETRITUS (3)	X	X	MUCK FROM RUNOFF and	***MODERATE (-1)***
MUCK/SILT (2)	X	X	CONSTRUCTION	LOW (0)
ARTIFIC. (0)				NONE (1)

TOTAL NUMBER OF SUBSTRATE TYPES: >4 (2) **<4 (0)**
NOTE: (ignore sludge that originates from point sources: score is based on natural substrates)
COMMENTS: Concrete slabs, boulders, culvert and other debris in area. Artificial.

2) INSTREAM COVER COVER SCORE 20

TYPE (Check all that Apply)	AMOUNT (Check only one or Check 2 and AVERAGE)
UNDERCUT BANKS (1)	
OVERHANGING VEGETATION (1)	***EXTENSIVE >75% (11)***
DEEP POOLS (2)	MODERATE 25-75% (7)
ROOTWADS (1)	SPARSE 5-25% (3)
SHALLOWS (IN SLOW WATER)(1)	NEARLY ABSENT <5% (1)
OXBOWS (1)	
AQUATIC MACROPHYTES(1)	
LOGS OR WOODY DEBRIS(1)	
BOULDERS (1)	

COMMENTS: Large pond in area. Significant filamentous algae in stream.

3) CHANNEL MORPHOLOGY: (Check ONLY ONE per Category or Check 2 and AVERAGE) CHANNEL SCORE 15

SINUOSITY	DEVELOPMENT	CHANNELIZATION	STABILITY	MODIFICATION/OTHER--NONE	
HIGH (4)	EXCELLENT (7)	NONE (6)	***HIGH (3)***	***IMPOUND***	SNAGGING
MODERATE (3)	***GOOD (5)***	***RECOVERED (4)***	MODERATE (2)	ISLAND	RELOCATION
LOW (2)	FAIR (3)	RECOVERING (3)	LOW (1)	***CANOPY REMOVAL***	LEVEED
NONE (1)	POOR (1)	RECENT OR NO		DREDGING	***BANK SHAPING***
		RECOVERY (1)		***ONE SIDE CHANNEL MODIFICATION***	

COMMENTS: Road and dam on left hand side looking downstream

4) RIPARIAN ZONE AND BANK EROSION: Check ONE box or Check 2 and average RIPARIAN SCORE 6
River Right Looking Downstream

RIPARIAN WIDTH LR (per bank)	EROSION/RUNOFF-FLOODPLAIN QUAL	BANK EROSION LR (per bank
WIDE >150 ft (4) LR	FOREST, SWAMP (3) LR (per bank)	***NONE OR LITTLE (3)***
MODERATE 30-150 ft (3) LR	SHRUB OR OLD FIELD (2)	MODERATE (2)
NARROW 15-30 ft (2) LR	CONSERV. TILLAGE (1)	HEAVY OR SEVERE (1)
VERY NARROW 3-15 ft.(1)	***FENCED PASTURE (1) R***	Potential for sediment to
NONE (0)	RESID, PARK NEW FIELD (1)	Enter the area from the road
	URBAN OR INDUSTRIAL (0)	Located above the stream
	OPEN PASTURE/ROW CROP (0)	
	MINING/CONSTRUCTION (0)	

COMMENTS: The left floodplain contained the entrance road to Padanaram.

5) POOL/GLIDE AND RIFFLE/RUN QUALITY POOL SCORE 8

MAX. DEPTH (Check 1)	MORPHOLOGY (Check 1)	POOL/RUN/RIFFLE CURRENT VELOCITY
>4 ft (6)	***POOL WIDTH > RIFFLE WIDTH (2)***	(Check all that apply)
2.4-4 ft(4)	POOL WIDTH = RIFFLE WIDTH (1)	TORRENTIAL (-1) ***SLOW (1)***
1.2-2.4 ft (2)	POOL WIDTH < RIFFLE WIDTH (0)	***EDDIES (1)*** INTERSTITIAL (-1)
<1.2 ft (1)		FAST (1) INTERMITTENT (-2)
<0.6 ft (0) (No Pool=0)		MODERATE (1)

COMMENTS: The pool had a hardpan bottom with some logs on the bottom. RIFFLE SCORE -1

RIFFLE/RUN DEPTH	RIFFLE/RUN SUBSTRATE	RIFFLE/RUN EMBEDDEDNESS
GENERALLY >4"MAX >20" (4)	STABLE (Cobble, Boulder) (2)	***EXTENSIVE (-1)***
GENERALLY>4 in. MAX <20 in (3)	MOD.STABLE (Pea Gravel) (1)	NONE (2)
GENERALLY 2-4 in (1)	***UNSTABLE (Gravel, Sand) (0)***	LOW (1)
GENERALLY <2 in Riffle (0)	The substrate was mostly silt	MODERATE (0)
NO RIFFLE (0)	with some sand.	

COMMENTS:

6) GRADIENT (FEET/MILE): 13.2 %POOL 60 %RIFFLE 20 %RUN 10 GRADIENT SCORE 6

The pools had significant macrophytes and green algae: Potamogeton, spike rush, sweet flag. Extensive biomass of filamentous algae suggests high nutrient loading. Evidence suggests previous damming and rip-rap. The banks consisted of an assortment of shrubs and forbs with some box elder and sycamores.

There was some odor. In the area was evidence of road work without silt barriers, evidence of tree removal, and a floodplain area converted to gardens.

STREAM: Indian CK near Indian CK Church RIVER MILE: Station 5 DATE: 9/16/98 QHEI SCORE **72**

1) SUBSTRATE: (Check ONLY Two Substrate Type Boxes: Check all types present) SUBSTRATE SCORE 20

TYPE	POOL	RIFFLE	SUBSTRATE ORIGIN (ALL)	SILT COVER (check one)
BLDER/SLAB(10)	X	X	***LIMESTONE(1)***	SILT HEAVY(-2)
BOULDER (9)		X	TILLS (1)	***SILT-NORM. (0)***
COBBLE(8)		X	SHALE (-1)	SLT-MOD.(-1)
GRAVEL(7)	X	X	COAL FINES (-2)	SLT-FREE (1)
SAND (6)			HARDPAN (0)	Extent of Embeddedness
BEDROCK(5)			RIP/RAP(0)	(check one)
HARDPAN (4)			SANDSTONE(0)	EXTENSIVE (-2)
DETRITUS (3)	X	X	SILT FROM RUNOFF	***MODERATE (-1)***
MUCK/SILT (2)	X			LOW (0)
ARTIFIC. (0)				NONE (1)

TOTAL NUMBER OF SUBSTRATE TYPES: ***>4 (2)*** <4 (0)
NOTE: (ignore sludge that originates from point sources: score is based on natural substrates)
COMMENTS: Measured 18"x11" limestone slab

2) INSTREAM COVER COVER SCORE 18

TYPE (Check all that Apply)	AMOUNT (Check only one or Check 2 and AVERAGE)
UNDERCUT BANKS (1)	
OVERHANGING VEGETATION (1)	***EXTENSIVE >75% (11)***
DEEP POOLS (2)	MODERATE 25-75% (7)
ROOTWADS (1)	SPARSE 5-25% (3)
SHALLOWS (IN SLOW WATER)(1)	NEARLY ABSENT <5% (1)
OXBOWS (1)	
AQUATIC MACROPHYTES(1)	
LOGS OR WOODY DEBRIS(1)	
BOULDERS (1)	

COMMENTS: Large pond in area. Large helgrammites were noted.

3) CHANNEL MORPHOLOGY: (Check ONLY ONE per Category or Check 2 and AVERAGE) CHANNEL SCORE 18

SINUOSITY	DEVELOPMENT	CHANNELIZATION	STABILITY	MODIFICATION/OTHER--NONE	
HIGH (4)	***EXCELLENT (7)***	***NONE (6)***	HIGH (3)	IMPOUND	SNAGGING
MODERATE (3)	GOOD (5)	RECOVERED (4)	***MODERATE (2)***	ISLAND	RELOCATION
LOW (2)	FAIR (3)	RECOVERING (3)	LOW (1)	CANOPY REMOVAL	LEVEED
NONE (1)	POOR (1)	RECENT OR NO		DREDGING	BANK SHAPING
		RECOVERY (1)		ONE SIDE CHANNEL MODIFICATION	
				Fallen Trees noted in area	

COMMENTS:

4) RIPARIAN ZONE AND BANK EROSION: Check ONE box or Check 2 and average RIPARIAN SCORE 4
River Right Looking Downstream

RIPARIAN WIDTH LR (per bank)	EROSION/RUNOFF-FLOODPLAIN QUAL	BANK EROSION LR (per bank
WIDE >150 ft (4) LR	FOREST, SWAMP (3) LR (per bank)	NONE OR LITTLE (3)
MODERATE 30-150 ft (3) LR	SHRUB OR OLD FIELD (2)	***MODERATE (2)***
NARROW 15-30 ft (2) LR	CONSERV. TILLAGE (1)	HEAVY OR SEVERE (1)
VERY NARROW 3-15 ft.(1)	FENCED PASTURE (1) R	
NONE (0)	RESID, PARK NEW FIELD (1)	
	URBAN OR INDUSTRIAL (0)	
	OPEN PASTURE/ROW CROP (0)	
	MINING/CONSTRUCTION (0)	

COMMENTS: Bankside road leading into agricultural areas. Banks had very little vegetation.

5) POOL/GLIDE AND RIFFLE/RUN QUALITY POOL SCORE 8

MAX. DEPTH (Check 1)	MORPHOLOGY (Check 1)	POOL/RUN/RIFFLE CURRENT VELOCITY
>4 ft (6)	***POOL WIDTH > RIFFLE WIDTH (2)***	(Check all that apply)
2.4-4 ft (4)	POOL WIDTH = RIFFLE WIDTH (1)	TORRENTIAL (-1) SLOW (1)
1.2-2.4 ft (2)	POOL WIDTH < RIFFLE WIDTH (0)	***EDDIES (1)*** INTERSTITIAL (-1)
<1.2 ft (1)		FAST (1) INTERMITTENT (-2)
<0.6 ft (0) (No Pool=0)		***MODERATE (1)***

COMMENTS: Logs and debris in the area. (See photos) RIFFLE SCORE 4

RIFFLE/RUN DEPTH	RIFFLE/RUN SUBSTRATE	RIFFLE/RUN EMBEDDEDNESS
GENERALLY >4"MAX >20" (4)	***STABLE (Cobble, Boulder) (2)***	EXTENSIVE (-1)
GENERALLY>4 in. MAX <20 in (3)	MOD.STABLE (Pea Gravel) (1)	NONE (2)
GENERALLY 2-4 in (1)	UNSTABLE (Gravel, Sand) (0)	***LOW (1)***
GENERALLY <2 in Riffle (0)		MODERATE (0)
NO RIFFLE (0)		

COMMENTS:

6) GRADIENT (FEET/MILE): 6.2 %POOL 50 %RIFFLE 40 %RUN 10 GRADIENT SCORE 10

STREAM: Spring Creek RIVER MILE: Station 6 DATE: 9/16/98 QHEI SCORE **74.5**

1) SUBSTRATE: (Check ONLY Two Substrate Type Boxes: Check all types present) SUBSTRATE SCORE 17

TYPE	POOL	RIFFLE	SUBSTRATE ORIGIN (ALL)	SILT COVER (check one)
BLDER/SLAB(10)			LIMESTONE(1)	SILT HEAVY(-2)
BOULDER (9)			TILLS (1)	***SILT-NORM. (0)***
COBBLE(8)	X		SHALE (-1)	SLT-MOD.(-1)
GRAVEL(7)	X	X	COAL FINES (-2)	SLT-FREE (1)
SAND (6)			HARDPAN (0)	Extent of Embeddedness
BEDROCK(5)			RIP/RAP(0)	(check one)
HARDPAN (4)		X	***SANDSTONE(0)***	EXTENSIVE (-2)
DETRITUS (3)	X	X		MODERATE (-1)
MUCK/SILT (2)	X	X		***LOW (0)***
ARTIFIC. (0)				NONE (1)

TOTAL NUMBER OF SUBSTRATE TYPES: **>4 (2)** <4 (0)
NOTE: (ignore sludge that originates from point sources: score is based on natural substrates)
COMMENTS: Larger rocks 4.5', 9.75'

2) INSTREAM COVER COVER SCORE 11

TYPE (Check all that Apply)	AMOUNT (Check only one or Check 2 and AVERAGE)
UNDERCUT BANKS (1)	
OVERHANGING VEGETATION (1)	EXTENSIVE >75% (11)
DEEP POOLS (2)	***MODERATE 25-75% (7)***
ROOTWADS (1)	SPARSE 5-25% (3)
SHALLOWS (IN SLOW WATER)(1)	NEARLY ABSENT <5% (1)
OXBOWS (1)	
AQUATIC MACROPHYTES(1)	
LOGS OR WOODY DEBRIS(1)	
BOULDERS (1)	

COMMENTS: Slab rocks were present along bank.

3) CHANNEL MORPHOLOGY: (Check ONLY ONE per Category or Check 2 and AVERAGE) CHANNEL SCORE 16

SINUOSITY	DEVELOPMENT	CHANNELIZATION	STABILITY	MODIFICATION/OTHER--NONE	
HIGH (4)	EXCELLENT (7)	***NONE (6)***	HIGH (3)	IMPOUND	SNAGGING
MODERATE (3)	***GOOD (5)***	RECOVERED (4)	***MODERATE (2)***	ISLAND	RELOCATION
LOW (2)	FAIR (3)	RECOVERING (3)	LOW (1)	CANOPY REMOVAL	LEVEED
NONE (1)	POOR (1)	RECENT OR NO		DREDGING	BANK SHAPING
		RECOVERY (1)		ONE SIDE CHANNEL MODIFICATION	
				Field in the distance	

COMMENTS:

4) RIPARIAN ZONE AND BANK EROSION: Check ONE box or Check 2 and average RIPARIAN SCORE 6.5
River Right Looking Downstream

RIPARIAN WIDTH LR (per bank)	EROSION/RUNOFF-FLOODPLAIN QUAL	BANK EROSION LR (per bank
WIDE >150 ft (4) LR	***FOREST, SWAMP (3) L*** (per bank)	NONE OR LITTLE (3)
MODERATE 30-150 ft (3)	SHRUB OR OLD FIELD (2)	***MODERATE (2)***
NARROW 15-30 ft (2)	CONSERV. TILLAGE (1)	HEAVY OR SEVERE (1)
VERY NARROW 3-15 ft.(1)	FENCED PASTURE (1) R	
NONE (0)	RESID, PARK NEW FIELD (1)	
	URBAN OR INDUSTRIAL (0)	
	OPEN PASTURE/ROW CROP (0) R	
	MINING/CONSTRUCTION (0)	

COMMENTS: Attractive area with mature trees.

5) POOL/GLIDE AND RIFFLE/RUN QUALITY POOL SCORE 8

MAX. DEPTH (Check 1)	MORPHOLOGY (Check 1)	POOL/RUN/RIFFLE CURRENT VELOCITY
>4 ft (6)	***POOL WIDTH > RIFFLE WIDTH (2)***	(Check all that apply)
2.4-4 ft (4)	POOL WIDTH = RIFFLE WIDTH (1)	TORRENTIAL (-1) SLOW (1)
1.2-2.4 ft (2)	POOL WIDTH < RIFFLE WIDTH (0)	***EDDIES (1)*** INTERSTITIAL (-1)
<1.2 ft (1)		FAST (1) INTERMITTENT (-2)
<0.6 ft (0) (No Pool=0)		***MODERATE (1)***

COMMENTS: Small isolated pool with significant fish population. RIFFLE SCORE 6

RIFFLE/RUN DEPTH	RIFFLE/RUN SUBSTRATE	RIFFLE/RUN EMBEDDEDNESS
GENERALLY >4"MAX >20" (4)	***STABLE (Cobble, Boulder) (2)***	EXTENSIVE (-1)
GENERALLY>4 in. MAX <20 in (3)	MOD.STABLE (Pea Gravel) (1)	NONE (2)
GENERALLY 2-4 in (1)	UNSTABLE (Gravel, Sand) (0)	LOW (1)
GENERALLY <2 in Riffle (0)		***MODERATE (0)***
NO RIFFLE (0)		

COMMENTS:

6) GRADIENT (FEET/MILE): 16.0 %POOL 33 %RIFFLE 33 %RUN 33 GRADIENT SCORE 10

Current 3.5 to 4.0 ft/sec.; several large riparian sycamore trees were noted. Springs elsewhere in the watershed. Several cows noted along and in the stream driving to site. Fish noted: rainbow darter, fantail darter, greenside darter, rock bass, creek chub, silverjaw minnow, stoneroller, banded sculpin. Snails and crayfish found in the seine haul.

STREAM: Town Branch RIVER MILE: Station 7 DATE: 9/16/98 QHEI SCORE **49**

1) SUBSTRATE: (Check ONLY Two Substrate Type Boxes: Check all types present) SUBSTRATE SCORE 13

TYPE	POOL	RIFFLE	SUBSTRATE ORIGIN (ALL)	SILT COVER (check one)
BLDER/SLAB(10)			***LIMESTONE(1)***	SILT HEAVY(-2)
BOULDER (9)		X	TILLS (1)	SILT-NORM. (0)
COBBLE(8)	X		SHALE (-1)	***SLT-MOD.(-1)***
GRAVEL(7)	X	X	COAL FINES (-2)	SLT-FREE (1)
SAND (6)	X	X	HARDPAN (0)	Extent of Embeddedness
BEDROCK(5)			RIP/RAP(0)	(check one)
HARDPAN (4)		X	SANDSTONE(0)	EXTENSIVE (-2)
DETRITUS (3)	X	X		***MODERATE (-1)***
MUCK/SILT (2)	X	X		LOW (0)
ARTIFIC. (0)				NONE (1)

TOTAL NUMBER OF SUBSTRATE TYPES: ***>4 (2)*** <4 (0)

NOTE: (ignore sludge that originates from point sources: score is based on natural substrates)

COMMENTS: First area where we observed a significant amount of gravel.

2) INSTREAM COVER COVER SCORE 7

TYPE (Check all that Apply)	AMOUNT (Check only one or Check 2 and AVERAGE)
UNDERCUT BANKS (1)	
OVERHANGING VEGETATION (1)	EXTENSIVE >75% (11)
DEEP POOLS (2)	MODERATE 25-75% (7)
ROOTWADS (1)	***SPARSE 5-25% (3)***
SHALLOWS (IN SLOW WATER)(1)	NEARLY ABSENT <5% (1)
OXBOWS (1)	
AQUATIC MACROPHYTES(1)	
LOGS OR WOODY DEBRIS(1)	
BOULDERS (1)	

COMMENTS: Waterwillow plants

3) CHANNEL MORPHOLOGY: (Check ONLY ONE per Category or Check 2 and AVERAGE) CHANNEL SCORE 11

SINUOSITY	DEVELOPMENT	CHANNELIZATION	STABILITY	MODIFICATION/OTHER--NONE	
HIGH (4)	EXCELLENT (7)	NONE (6)	HIGH (3)	IMPOUND	SNAGGING
MODERATE (3)	GOOD (5)	***RECOVERED (4)***	MODERATE (2)	ISLAND	RELOCATION
LOW (2)	***FAIR (3)***	RECOVERING (3)	***LOW (1)***	CANOPY REMOVAL	***LEVEED***
NONE (1)	POOR (1)	RECENT OR NO		DREDGING	BANK SHAPING
		RECOVERY (1)		ONE SIDE CHANNEL MODIFICATION	
				Old fields present	

COMMENTS: Previous flood control work in the area.

4) RIPARIAN ZONE AND BANK EROSION: Check ONE box or Check 2 and average RIPARIAN SCORE 2

River Right Looking Downstream

RIPARIAN WIDTH LR (per bank)	EROSION/RUNOFF-FLOODPLAIN QUAL	BANK EROSION LR (per bank
WIDE >150 ft (4)	FOREST, SWAMP (3) L (per bank)	NONE OR LITTLE (3)
MODERATE 30-150 ft (3)	SHRUB OR OLD FIELD (2)	MODERATE (2)
NARROW 15-30 ft (2)	CONSERV. TILLAGE (1)	***HEAVY OR SEVERE (1)***
VERY NARROW 3-15 ft.(1) LR	FENCED PASTURE (1)	
NONE (0)	RESID, PARK NEW FIELD (1)	
	URBAN OR INDUSTRIAL (0)	
	OPEN PASTURE/ROW CROP (0) LR	
	MINING/CONSTRUCTION (0)	

COMMENTS:

5) POOL/GLIDE AND RIFFLE/RUN QUALITY POOL SCORE 5

MAX. DEPTH (Check 1)	MORPHOLOGY (Check 1)	POOL/RUN/RIFFLE CURRENT VELOCITY
>4 ft (6)	***POOL WIDTH > RIFFLE WIDTH (2)***	(Check all that apply)
2.4-4 ft (4)	POOL WIDTH = RIFFLE WIDTH (1)	TORRENTIAL (-1) ***SLOW (1)***
1.2-2.4 ft (2)	POOL WIDTH < RIFFLE WIDTH (0)	EDDIES (1) INTERSTITIAL (-1)
<1.2 ft (1)		FAST (1) INTERMITTENT (-2)
<0.6 ft (0) (No Pool=0)		MODERATE (1)

COMMENTS:.

RIFFLE SCORE 1

RIFFLE/RUN DEPTH	RIFFLE/RUN SUBSTRATE	RIFFLE/RUN EMBEDDEDNESS
GENERALLY >4"MAX >20" (4)	STABLE (Cobble, Boulder) (2)	EXTENSIVE (-1)
GENERALLY>4 in. MAX <20 in (3)	***MOD.STABLE (Pea Gravel) (1)***	NONE (2)
GENERALLY 2-4 in (1)	UNSTABLE (Gravel, Sand) (0)	LOW (1)
GENERALLY <2 in Riffle (0)		***MODERATE (0)***
NO RIFFLE (0)		

COMMENTS: Very low flow.

6) GRADIENT (FEET/MILE): 21.0 %POOL 60 %RIFFLE 30 %RUN 10 GRADIENT SCORE 10

Banks almost vertical with high potential for erosion. Riparian trees in the distance. Scum and oil below bridge. Water snake taken. Fish observed: bluegill, creek chub, smallmouth bass, golden redhorse, shiner unid, bluntnose minnow. Bat habitat noted--dead trees with loose bark.

STREAM: Popcorn Creek RIVER MILE: Station 8 DATE: 9/16/98 QHEI SCORE **66**

1) SUBSTRATE: (Check ONLY Two Substrate Type Boxes: Check all types present) SUBSTRATE SCORE 15

TYPE	POOL	RIFFLE	SUBSTRATE ORIGIN (ALL)	SILT COVER (check one)
BLDER/SLAB(10)	X	X	***LIMESTONE(1)***	SILT HEAVY(-2)
BOULDER (9)		X	TILLS (1)	***SILT-NORM. (0)***
COBBLE(8)			SHALE (-1)	SLT-MOD.(-1)
GRAVEL(7)			COAL FINES (-2)	SLT-FREE (1)
SAND (6)			HARDPAN (0)	Extent of Embeddedness
BEDROCK(5)		X	RIP/RAP(0)	(check one)
HARDPAN (4)		X	SANDSTONE(0)	EXTENSIVE (-2)
DETRITUS (3)	X			MODERATE (-1)
MUCK/SILT (2)		X		***LOW (0)***
ARTIFIC. (0)				NONE (1)

TOTAL NUMBER OF SUBSTRATE TYPES: ***>4 (2)*** <4 (0)

NOTE: (ignore sludge that originates from point sources: score is based on natural substrates)

COMMENTS: Bedrock slabs underlying riffle; waterwillow.

2) INSTREAM COVER COVER SCORE 7

TYPE (Check all that Apply)	AMOUNT (Check only one or Check 2 and AVERAGE)
UNDERCUT BANKS (1)	
OVERHANGING VEGETATION (1)	EXTENSIVE >75% (11)
DEEP POOLS (2)	MODERATE 25-75% (7)
ROOTWADS (1)	***SPARSE 5-25% (3)***
SHALLOWS (IN SLOW WATER)(1)	NEARLY ABSENT <5% (1)
OXBOWS (1)	Exposed bedrock in the riffles
AQUATIC MACROPHYTES(1)	
LOGS OR WOODY DEBRIS(1)	
BOULDERS (1)	

COMMENTS: Farms and fields upstream.

3) CHANNEL MORPHOLOGY: (Check ONLY ONE per Category or Check 2 and AVERAGE) CHANNEL SCORE 17

SINUOSITY	DEVELOPMENT	CHANNELIZATION	STABILITY	MODIFICATION/OTHER--***NONE***	
HIGH (4)	EXCELLENT (7)	***NONE (6)***	***HIGH (3)***	IMPOUND	SNAGGING
MODERATE (3)	***GOOD (5)***	RECOVERED (4)	MODERATE (2)	ISLAND	RELOCATION
LOW (2)	FAIR (3)	RECOVERING (3)	LOW (1)	CANOPY REMOVAL	LEVEED
NONE (1)	POOR (1)	RECENT OR NO		DREDGING	BANK SHAPING
		RECOVERY (1)		ONE SIDE CHANNEL MODIFICATION	
				Old fields present	

COMMENTS:

4) RIPARIAN ZONE AND BANK EROSION: Check ONE box or Check 2 and average RIPARIAN SCORE 9

River Right Looking Downstream

RIPARIAN WIDTH LR (per bank)	EROSION/RUNOFF-FLOODPLAIN QUAL	BANK EROSION LR (per bank
WIDE >150 ft (4)	FOREST, SWAMP (3) L (per bank)	***NONE OR LITTLE (3)***
MODERATE 30-150 ft (3) R	**SHRUB OR OLD FIELD (2)**	MODERATE (2)
NARROW 15-30 ft (2) L	CONSERV. TILLAGE (1)	HEAVY OR SEVERE (1)
VERY NARROW 3-15 ft.(1)	FENCED PASTURE (1)	
NONE (0)	RESID, PARK NEW FIELD (1)	
	URBAN OR INDUSTRIAL (0)	
	OPEN PASTURE/ROW CROP (0) LR	
	MINING/CONSTRUCTION (0)	

COMMENTS:

5) POOL/GLIDE AND RIFFLE/RUN QUALITY POOL SCORE 5

MAX. DEPTH (Check 1)	MORPHOLOGY (Check 1)	POOL/RUN/RIFFLE CURRENT VELOCITY (Check all that apply)
>4 ft (6)	***POOL WIDTH > RIFFLE WIDTH (2)***	TORRENTIAL (-1) ***SLOW (1)***
2.4-4 ft (4)	POOL WIDTH = RIFFLE WIDTH (1)	***EDDIES (1)*** INTERSTITIAL (-1)
1.2-2.4 ft (2)	POOL WIDTH < RIFFLE WIDTH (0)	FAST (1) INTERMITTENT (-2)
<1.2 ft (1)		MODERATE (1)
<0.6 ft (0) (No Pool=0)		

COMMENTS:.

RIFFLE SCORE 3

RIFFLE/RUN DEPTH	RIFFLE/RUN SUBSTRATE	RIFFLE/RUN EMBEDDEDNESS
GENERALLY >4"MAX >20" (4)	***STABLE (Cobble, Boulder) (2)***	EXTENSIVE (-1)
GENERALLY>4 in. MAX <20 in (3)	MOD.STABLE (Pea Gravel) (1)	NONE (2)
GENERALLY 2-4 in (1)	UNSTABLE (Gravel, Sand) (0)	***LOW (1)***
GENERALLY <2 in Riffle (0)		MODERATE (0)
NO RIFFLE (0)		

COMMENTS: Low flow.

6) GRADIENT (FEET/MILE): 29.3 %POOL 55 %RIFFLE 35 %RUN 10 GRADIENT SCORE 10

Muskrats noted. Bulrush noted. Fish taken: bluntnose minnow, stoneroller, brook silverside, creek chub, fantail darter, rosefin shiner. Large cornfield upstream, young water striders noted, milky inflow downstream.

STREAM: Little Indian CK RIVER MILE: Station 9 DATE: 9/16/98 QHEI SCORE **77.5**

1) SUBSTRATE: (Check ONLY Two Substrate Type Boxes: Check all types present) SUBSTRATE SCORE 17

TYPE	POOL	RIFFLE	SUBSTRATE ORIGIN (ALL)	SILT COVER (check one)
BLDER/SLAB(10)			LIMESTONE(1)	SILT HEAVY(-2)
BOULDER (9)		X	TILLS (1)	**SILT-NORM. (0)**
COBBLE(8)		X	SHALE (-1)	SLT-MOD.(-1)
GRAVEL(7)		X	COAL FINES (-2)	SLT-FREE (1)
SAND (6)		X	HARDPAN (0)	Extent of Embeddedness
BEDROCK(5)		X	RIP/RAP(0)	(check one)
HARDPAN (4)		X	***SANDSTONE(0)***	EXTENSIVE (-2)
DETRITUS (3)	X			MODERATE (-1)
MUCK/SILT (2)	X	X		LOW (0)
ARTIFIC. (0)				NONE (1)

TOTAL NUMBER OF SUBSTRATE TYPES: ***>4 (2)*** <4 (0)

NOTE: (ignore sludge that originates from point sources: score is based on natural substrates)

COMMENTS: Large sycamore with rootwads.

2) INSTREAM COVER COVER SCORE 18

TYPE (Check all that Apply)	AMOUNT (Check only one or Check 2 and AVERAGE)
UNDERCUT BANKS (1)	
OVERHANGING VEGETATION (1)	***EXTENSIVE >75% (11)***
DEEP POOLS (2)	MODERATE 25-75% (7)
ROOTWADS (1)	SPARSE 5-25% (3)
SHALLOWS (IN SLOW WATER)(1)	NEARLY ABSENT <5% (1)
OXBOWS (1)	
AQUATIC MACROPHYTES(1)	
LOGS OR WOODY DEBRIS(1)	
BOULDERS (1)	

COMMENTS: Large sycamores with rootwads

3) CHANNEL MORPHOLOGY: (Check ONLY ONE per Category or Check 2 and AVERAGE) CHANNEL SCORE 17

SINUOSITY	DEVELOPMENT	CHANNELIZATION	STABILITY	MODIFICATION/OTHER--***NONE***	
HIGH (4)	EXCELLENT (7)	***NONE (6)***	***HIGH (3)***	IMPOUND	SNAGGING
MODERATE (3)	***GOOD (5)***	RECOVERED (4)	MODERATE (2)	ISLAND	RELOCATION
LOW (2)	FAIR (3)	RECOVERING (3)	LOW (1)	CANOPY REMOVAL	LEVEED
NONE (1)	POOR (1)	RECENT OR NO		DREDGING	BANK SHAPING
		RECOVERY (1)		ONE SIDE CHANNEL MODIFICATION	
				Old fields present	

COMMENTS:

4) RIPARIAN ZONE AND BANK EROSION: Check ONE box or Check 2 and average RIPARIAN SCORE 6

River Right Looking Downstream

RIPARIAN WIDTH LR (per bank)	EROSION/RUNOFF-FLOODPLAIN QUAL	BANK EROSION LR (per bank
WIDE >150 ft (4)	FOREST, SWAMP (3) L (per bank)	***NONE OR LITTLE (3)***
MODERATE 30-150 ft (3) LR	SHRUB OR OLD FIELD (2)	MODERATE (2)
NARROW 15-30 ft (2)	CONSERV. TILLAGE (1)	HEAVY OR SEVERE (1)
VERY NARROW 3-15 ft.(1)	FENCED PASTURE (1)	
NONE (0)	RESID, PARK NEW FIELD (1)	
	URBAN OR INDUSTRIAL (0)	
	OPEN PASTURE/ROW CROP (0) LR	
	MINING/CONSTRUCTION (0)	

COMMENTS: Hayfield

5) POOL/GLIDE AND RIFFLE/RUN QUALITY POOL SCORE 7

MAX. DEPTH (Check 1)	MORPHOLOGY (Check 1)	POOL/RUN/RIFFLE CURRENT VELOCITY
>4 ft (6)	***POOL WIDTH > RIFFLE WIDTH (2)***	(Check all that apply)
2.4-4 ft (4)	POOL WIDTH = RIFFLE WIDTH (1)	TORRENTIAL (-1) ***SLOW (1)***
1.2-2.4 ft (2)	POOL WIDTH < RIFFLE WIDTH (0)	EDDIES (1) INTERSTITIAL (-1)
<1.2 ft (1)		FAST (1) INTERMITTENT (-2)
<0.6 ft (0) (No Pool=0)		MODERATE (1)

COMMENTS:. RIFFLE SCORE 2.5

RIFFLE/RUN DEPTH	RIFFLE/RUN SUBSTRATE	RIFFLE/RUN EMBEDDEDNESS
GENERALLY >4"MAX >20" (4)	**STABLE (Cobble, Boulder) (2)**	EXTENSIVE (-1)
GENERALLY>4 in. MAX <20 in (3)	**MOD.STABLE (Pea Gravel) (1)**	NONE (2)
GENERALLY 2-4 in (1)	UNSTABLE (Gravel, Sand) (0)	LOW (1)
GENERALLY <2 in Riffle (0)		***MODERATE (0)***
NO RIFFLE (0)		

COMMENTS:

6) GRADIENT (FEET/MILE): 17.6 %POOL 33 %RIFFLE 33 %RUN 33 GRADIENT SCORE 10

34" dbh sycamore, multiflora rose, jewelweed. Incidental fish catch: smallmouth bass, longear sunfish, bluntnose minnow, white sucker, golden redhorse, bluegill, common shiner, fantail darter

STREAM: Indian CK RIVER MILE: Station 10 DATE: 9/16/98 QHEI SCORE 68

1) SUBSTRATE: (Check ONLY Two Substrate Type Boxes: Check all types present) SUBSTRATE SCORE 18

TYPE	POOL	RIFFLE	SUBSTRATE ORIGIN (ALL)	SILT COVER (check one)
BLDER/SLAB(10)		X	**LIMESTONE(1)**	SILT HEAVY(-2)
BOULDER (9)			TILLS (1)	***SILT-NORM. (0)***
COBBLE(8)			SHALE (-1)	SLT-MOD.(-1)
GRAVEL(7)		X	COAL FINES (-2)	SLT-FREE (1)
SAND (6)		X	HARDPAN (0)	Extent of Embeddedness
BEDROCK(5)		X	RIP/RAP(0)	(check one)
HARDPAN (4)	X	X	**SANDSTONE(0)**	EXTENSIVE (-2)
DETRITUS (3)	X	X		MODERATE (-1)
MUCK/SILT (2)	X	X		***LOW (0)***
ARTIFIC. (0)				NONE (1)

TOTAL NUMBER OF SUBSTRATE TYPES: ***>4 (2)*** <4 (0)
NOTE: (ignore sludge that originates from point sources: score is based on natural substrates)
COMMENTS: Debris field along edge of riffle.

2) INSTREAM COVER COVER SCORE 7

TYPE (Check all that Apply)	AMOUNT (Check only one or Check 2 and AVERAGE)
UNDERCUT BANKS (1)	
OVERHANGING VEGETATION (1)	EXTENSIVE >75% (11)
DEEP POOLS (2)	MODERATE 25-75% (7)
ROOTWADS (1)	***SPARSE 5-25% (3)***
SHALLOWS (IN SLOW WATER)(1)	NEARLY ABSENT <5% (1)
OXBOWS (1)	
AQUATIC MACROPHYTES(1)	
LOGS OR WOODY DEBRIS(1)	
BOULDERS (1)	

COMMENTS: Large sycamore noted.

3) CHANNEL MORPHOLOGY: (Check ONLY ONE per Category or Check 2 and AVERAGE) CHANNEL SCORE 16

SINUOSITY	DEVELOPMENT	CHANNELIZATION	STABILITY	MODIFICATION/OTHER--***NONE***	
HIGH (4)	EXCELLENT (7)	***NONE (6)***	HIGH (3)	IMPOUND	SNAGGING
MODERATE (3)	***GOOD (5)***	RECOVERED (4)	***MODERATE (2)***	ISLAND	RELOCATION
LOW (2)	FAIR (3)	RECOVERING (3)	LOW (1)	CANOPY REMOVAL	LEVEED
NONE (1)	POOR (1)	RECENT OR NO		DREDGING	BANK SHAPING
		RECOVERY (1)		ONE SIDE CHANNEL MODIFICATION	
				Old fields present	

COMMENTS:

4) RIPARIAN ZONE AND BANK EROSION: Check ONE box or Check 2 and average RIPARIAN SCORE 8
River Right Looking Downstream

RIPARIAN WIDTH LR (per bank)	EROSION/RUNOFF-FLOODPLAIN QUAL	BANK EROSION LR (per bank
WIDE >150 ft (4) L	***FOREST, SWAMP (3) L*** (per bank)	***NONE OR LITTLE (3)***
MODERATE 30-150 ft (3) R	SHRUB OR OLD FIELD (2)	MODERATE (2)
NARROW 15-30 ft (2)	CONSERV. TILLAGE (1)	HEAVY OR SEVERE (1)
VERY NARROW 3-15 ft.(1)	FENCED PASTURE (1)	
NONE (0)	RESID, PARK NEW FIELD (1)	
	URBAN OR INDUSTRIAL (0)	
	OPEN PASTURE/ROW CROP (0) R	
	MINING/CONSTRUCTION (0)	

COMMENTS: Forested Hillside on the left; fields on the right

5) POOL/GLIDE AND RIFFLE/RUN QUALITY POOL SCORE 5

MAX. DEPTH (Check 1)	MORPHOLOGY (Check 1)	POOL/RUN/RIFFLE CURRENT VELOCITY
>4 ft (6)	***POOL WIDTH > RIFFLE WIDTH (2)***	(Check all that apply)
2.4-4 ft (4)	POOL WIDTH = RIFFLE WIDTH (1)	TORRENTIAL (-1) ***SLOW (1)***
1.2-2.4 ft (2)	POOL WIDTH < RIFFLE WIDTH (0)	EDDIES (1) INTERSTITIAL (-1)
<1.2 ft (1)		FAST (1) INTERMITTENT (-2)
<0.6 ft (0) (No Pool=0)		MODERATE (1)

COMMENTS:. RIFFLE SCORE 4

RIFFLE/RUN DEPTH	RIFFLE/RUN SUBSTRATE	RIFFLE/RUN EMBEDDEDNESS
GENERALLY >4"MAX >20" (4)	***STABLE (Cobble, Boulder) (2)***	EXTENSIVE (-1)
GENERALLY>4 in. MAX <20 in (3)	MOD.STABLE (Pea Gravel) (1)	NONE (2)
GENERALLY 2-4 in (1)	UNSTABLE (Gravel, Sand) (0)	***LOW (1)***
GENERALLY <2 in Riffle (0)		MODERATE (0)
NO RIFFLE (0)		

COMMENTS:

6) GRADIENT (FEET/MILE): 16.0 %POOL 43 %RIFFLE 33 %RUN 24 GRADIENT SCORE 10

Heavy growth of waterwillow. Fish taken: johnny darter, creek chub, sunfish, white sucker. Bullfrog found dead on stream bottom.

APPENDIX D

Habitat Bioassessment Sheets

74102

Waterbody Name	**Indian Creek and Tributaries**
Location	Opossum Creek
Reach/Milepoint	First tributary on Indian Creek
County	State--Indiana;
Ecoregion	Eastern Broadleaf Forest; Unglaciated IN
Station Number	One (1)
Investigators	Baker and Donan Engineering
Date	9/16/98
Time	8:30 AM
Agency/Organization	Donan Engineering and DNR Project
Hydrologic Unit Code	
Form Completed By	Baker
Reason For Survey	Bioassessment and Macroinvertebrates
Latitude/Longitude	38 degrees 45"; 86 degrees 46"
Site Descriptors Weather	Cloudy, overcast 72-75 degrees F
Physical Characterization/Water Quality	Clear, channelized in ag area
Riparian Zone/Instream Features	
Predominant Surrounding Land Use Was	Field and Pasture, **Agricultural**, Residential, Commercial, Industrial, other__________
Local Watershed Erosion	None Moderate Heavy
Nonpoint Sources of Pollution	**Agricultural**, Urban, Feedlots, **Roads**, Septics, Dams, other
Stream Width	8 feet 2 inches in pool
Velocity in Feet per Second	Less than 1 ft/sec; too shallow for meter
Average Depth Riffles	Abt 2-4 inches; shallow
Cross Sectional Area	< 1 square foot
Discharge (Cubic Feet per Second)	Discharge was minimal; <1 cfs
High Water Mark	None found
Dams? Where	Yes **No**
Channelization	Yes
Canopy Cover	**Open** Partly Open Partly Shaded Shaded
Sediment/Substrate	
Sediment Odors	Sewage Petroleum Chemical Anaerobic Some **Anaerobic from sediment**
Sediment Oils	Absent **Slight** Moderate Profuse

Sediment Deposits	Sludge Sawdust Fibers **Sand Relict Shells** Other ________
Undersides of rocks black?	Yes **No**
Water Quality Instruments Used: HACH Kit with HACH Conductivity Meter	Temperature 20.8 degrees Centigrade Dissolved Oxygen 8.0 mg/L PH 8.0 Conductivity 0.33 ms/cm Alkalinity 124 mg/L Other
Stream Type	Warm water headwater stream
Water Odors	Normal Sewage Petroleum Chemical None **Sediment anaerobic odors**
Water Surface Oils and Sheen	Slick Sheen Globs **Flecks** Other ________
Turbidity	**Clear** Slightly Turbid Turbid Opaque
Water Color	**Clear**
Habitat Assessment	
Primary--Substrate and Instream Cover	
1. Bottom Substrate/Available Cover	Excellent--16-20 Good--11-15 Fair--6-10 **Poor--0-5 3**
2. Embeddedness	Excellent--16-20 Good--11-15 Fair--6-10 **Poor--0-5 3**
3. Discharge and Habitats	Excellent--16-20 Good--11-15 Fair--6-10 **Poor--0-5 3**
Secondary--Channel Morphology	
4. Channel Alteration	Excellent--12-15 Good--8-11 Fair--4-7 **Poor--0-3 3**
5. Bottom Scouring and Deposition	Excellent--12-15 Good--8-11 Fair--4-7 **Poor--0-3 3**

6. Pool, Riffle, run bend ratio	Excellent--12-15 Good--8-11 Fair--4-7 **Poor--0-3**	**3**
Tertiary--Riparian and Bank Structure		
7. Bank Stability	**Excellent--9-10** Good--6-8 Fair--3-5 Poor--0-2	**9**
8. Bank Vegetation	**Excellent--9-10** Good--6-8 Fair--3-5 Poor--0-2	**9**
9. Streamside Cover	Excellent--9-10 Good--6-8 **Fair--3-5** Poor--0-2	**5**
Reference Station: 1=18, 2=18, 3=19, 4=13, 5=13, 6=14, 7=10, 8=10, 9=10		

41/125=32.8% of high quality reference

74102

Waterbody Name	**Indian Creek and Tributaries**
Location	Sulphur Creek; Indian Springs, IN 7.5 min quadrangle map
Reach/Milepoint	2nd tributary of Indian Creek
County	State--Indiana;
Ecoregion	Eastern Broadleaf Forest; Unglaciated IN
Station Number	Two (2)
Investigators	Baker and Donan Engineering
Date	9/16/98
Time	AM
Agency/Organization	Donan Engineering and DNR Project
Hydrologic Unit Code	
Form Completed By	Baker
Reason For Survey	Bioassessment and Macroinvertebrates
Latitude/Longitude	38 degrees 45"; 86 degrees 46"
Site Descriptors Weather	Cloudy, overcast 72-75 degrees F
Physical Characterization/Water Quality	Wooded; ag area upstream
Riparian Zone/Instream Features	
Predominant Surrounding Land Use Was	Field and Pasture, **Agricultural**, Residential, Commercial, Industrial, **Governmental**
Local Watershed Erosion	**None** Moderate Heavy
Nonpoint Sources of Pollution	**Agricultural,** Urban, Feedlots, **Roads,** **Septics,** Dams, other
Stream Width	27' 7" in pool
Velocity in Feet per Second	2.5 feet per second
Average Depth Riffles	Abt 2-4 inches; shallow (2", 3", 6")
Cross Sectional Area	< 1 square foot
Discharge (Cubic Feet per Second)	Discharge was minimal; <1 cfs
High Water Mark	9 feet above stream surface
Dams? Where	Yes **No**
Channelization	None Observed
Canopy Cover	Open Partly Open Partly Shaded Shaded
Sediment/Substrate	
Sediment Odors	Sewage Petroleum Chemical Anaerobic
Sediment Oils	**Absent** Slight Moderate Profuse

Sediment Deposits	Sludge Sawdust Fibers Sand Relict Shells Other **Muck in pools**
Undersides of rocks black?	Yes **No**
Water Quality Instruments Used: HACH Kit with HACH Conductivity Meter Current Meter	Temperature 20.9 degrees Centigrade Dissolved Oxygen 5.0 mg/L PH 7.5 Conductivity 0.83 ms/cm Alkalinity 159 mg/L Other
Stream Type	Warm water headwater stream
Water Odors	**Normal** Sewage Petroleum Chemical None
Water Surface Oils and Sheen	Slick Sheen Globs Flecks Other
Turbidity	**Clear** Slightly Turbid Turbid Opaque
Water Color	**Clear**
Habitat Assessment	
Primary--Substrate and Instream Cover	
1. Bottom Substrate/Available Cover	Excellent--16-20 Good--11-15 **Fair--6-10** **10** Poor--0-5
2. Embeddedness	Excellent--16-20 Good--11-15 **Fair--6-10** **10** **Poor--0-5**
3. Discharge and Habitats	Excellent--16-20 Good--11-15 **Fair--6-10** **10** Poor--0-5
Secondary--Channel Morphology	
4. Channel Alteration	Excellent--12-15 Good--8-11 **Fair--4-7** **6** Poor--0-3
5. Bottom Scouring and Deposition	Excellent--12-15 **Good--8-11** **8** Fair--4-7 Poor--0-3
6. Pool, Riffle, run bend ratio	Excellent--12-15 Good--8-11 **Fair--4-7** **6** Poor--0-3

Tertiary--Riparian and Bank Structure		
7. Bank Stability	Excellent--9-10 **Good--6-8** Fair--3-5 Poor--0-2	**8**
8. Bank Vegetation	Excellent--9-10 Good--6-8 **Fair--3-5** Poor--0-2	**5**
9. Streamside Cover	Excellent--9-10 **Good--6-8** Fair--3-5 Poor--0-2	**8**
Reference Station: 1=18, 2=18, 3=19, 4=13, 5=13, 6=14, 7=10, 8=10, 9=10		

71/125=59% of high quality reference

Waterbody Name	**Indian Creek and Tributaries**
Location	Indian Creek Downstream Above Sulphur Creek
Reach/Milepoint	
County	State--Indiana;
Ecoregion	Eastern Broadleaf Forest; Unglaciated IN
Station Number	Three (3)
Investigators	Baker and Donan Engineering
Date	9/16/98
Time	AM
Agency/Organization	Donan Engineering and DNR Project
Hydrologic Unit Code	
Form Completed By	Baker
Reason For Survey	Bioassessment and Macroinvertebrates
Latitude/Longitude	38.8 approx degrees ; 86.7 approx degrees
Site Descriptors Weather	Partly cloudy; warm
Physical Characterization/Water Quality	Wooded along stream; ag area
Riparian Zone/Instream Features	
Predominant Surrounding Land Use Was	Field and Pasture, **Agricultural**, **Residential** nearby, Commercial, Industrial
Local Watershed Erosion	**None** Moderate Heavy
Nonpoint Sources of Pollution	**Agricultural**, **Urban**, Feedlots, **Roads**, **Septics**, Dams, other ________
Stream Width	35' across in pool
Velocity in Feet per Second	0.5 feet per second
Average Depth Riffles	Abt 4 inches; shallow log jam dominated
Cross Sectional Area	
Discharge (Cubic Feet per Second)	Discharge was minimal; <1 cfs; stagnant
High Water Mark	10 feet above stream surface; water noted by locals to reach highway
Dams? Where	Yes **No**
Channelization	None Observed
Canopy Cover	Open Partly Open Partly Shaded Shaded
Sediment/Substrate	
Sediment Odors	Sewage Petroleum Chemical Anaerobic

Sediment Oils	**Absent** Slight Moderate Profuse
Sediment Deposits	Sludge Sawdust Fibers Sand Relict Shells Other **Muck in pools**
Undersides of rocks black?	Yes **No**
Water Quality Instruments Used: HACH Kit with HACH Conductivity Meter Current Meter	Temperature 22.2 degrees Centigrade **Dissolved Oxygen 2.0 mg/L* below critical level** PH 7.5 Conductivity 0.41 ms/cm Alkalinity 212 mg/L Other
Stream Type	Warm water headwater stream
Water Odors	**Normal** Sewage Petroleum Chemical **Methane odor from sediments**
Water Surface Oils and Sheen	Slick Sheen Globs Flecks **Iron Bacteria**
Turbidity	Clear **Slightly Turbid** Turbid Opaque
Water Color	**Some color present tannins??**
Habitat Assessment	
Primary--Substrate and Instream Cover	
1. Bottom Substrate/Available Cover	Excellent--16-20 Good--11-15 **Fair--6-10** **7** Poor--0-5
2. Embeddedness* silt was obvious at this site but few riffles. Skip to Low Gradient Stream characterization. All mud or clay with few rootwads	Excellent--16-20 Good--11-15 **Fair--6-10** **9** Poor--0-5
3. Discharge and Habitats	Excellent--16-20 Good--11-15 **Fair--6-10** **10** Poor--0-5
Secondary--Channel Morphology	
4. Channel Alteration	Excellent--12-15 Good--8-11 **Fair--4-7** **6** Poor--0-3
5. Bottom Scouring and Deposition The bottom of the pool did have some rocks	Excellent--12-15 **Good--8-11** **9** Fair--4-7 Poor--0-3

6. Pool, Riffle, run bend ratio	Excellent--12-15 Good--8-11 **Fair--4-7** Poor--0-3	**6**
Tertiary--Riparian and Bank Structure		
7. Bank Stability	Excellent--9-10 **Good--6-8** Fair--3-5 Poor--0-2	**8**
8. Bank Vegetation	Excellent--9-10 Good--6-8 Fair--3-5 **Poor--0-2**	**2**
9. Streamside Cover	Excellent--9-10 **Good--6-8** Fair--3-5 Poor--0-2	**6**
Reference Station: 1=18, 2=18, 3=19, 4=13, 5=13, 6=14, 7=10, 8=10, 9=10		

63/125=50% of high quality reference

Waterbody Name	**Indian Creek and Tributaries**
Location	Tributary of Indian Creek
Reach/Milepoint	Padanaram Commune
County	State--Indiana;
Ecoregion	Eastern Broadleaf Forest; Unglaciated IN
Station Number	Four (4)
Investigators	Baker and Donan Engineering
Date	9/16/98
Time	AM
Agency/Organization	Donan Engineering and DNR Project
Hydrologic Unit Code	
Form Completed By	Baker
Reason For Survey	Bioassessment and Macroinvertebrates
Latitude/Longitude	38.8 approx degrees ; 86.7 approx degrees
Site Descriptors Weather	Partly cloudy; warm
Physical Characterization/Water Quality	Modified for communal life; fields and some agricultural in flood plain
Riparian Zone/Instream Features	
Predominant Surrounding Land Use Was	**Field and Pasture, Agricultural, Residential** nearby, Commercial, Industrial
Local Watershed Erosion	**None** Moderate Heavy
Nonpoint Sources of Pollution	**Agricultural, Urban**, Feedlots, **Roads, Septics, Dams (7' handbuilt)**, Area modified for communal existence
Stream Width	<20' in pools
Velocity in Feet per Second	<1 foot per second
Average Depth Riffles	<2 inches; shallow
Cross Sectional Area	
Discharge (Cubic Feet per Second)	Discharge was minimal; <1 cfs
High Water Mark	None observed
Dams? Where	**Yes** No Small artificial impoundment in stream; large water supply reservoir near station.
Channelization	Some bankside alteration in conjunction with road construction
Canopy Cover	**Open** Partly Open Partly Shaded Shaded
Sediment/Substrate	
Sediment Odors	Sewage Petroleum Chemical **Anaerobic**

Sediment Oils	**Absent** Slight Moderate Profuse
Sediment Deposits	Sludge Sawdust Fibers Sand Relict Shells Other **Muck in pools**
Undersides of rocks black?	Yes **No**
Water Quality Instruments Used: HACH Kit with HACH Conductivity Meter Current Meter	Temperature 22.8 degrees Centigrade Dissolved Oxygen 9.0 mg/L PH 7.5 Conductivity 0.37 ms/cm Alkalinity 195 mg/L Other
Stream Type	Warm water headwater stream
Water Odors	Normal Sewage Petroleum Chemical **Anaerobic sediment odor**
Water Surface Oils and Sheen	Slick Sheen Globs Flecks
Turbidity	**Clear** Slightly Turbid Turbid Opaque
Water Color	
Habitat Assessment	
Primary--Substrate and Instream Cover	
1. Bottom Substrate/Available Cover	Excellent--16-20 **Good--11-15** **13** Fair--6-10 Poor--0-5
2. Embeddedness	Excellent--16-20 **Good--11-15** **11** Fair--6-10 Poor--0-5
3. Discharge and Habitats	Excellent--16-20 Good--11-15 **Fair--6-10** **6** Poor--0-5
Secondary--Channel Morphology	
4. Channel Alteration	Excellent--12-15 Good--8-11 **Fair--4-7** **6** Poor--0-3
5. Bottom Scouring and Deposition	Excellent--12-15 **Good--8-11** **9** Fair--4-7 Poor--0-3

6. Pool, Riffle, run bend ratio	Excellent--12-15 **Good--8-11** Fair--4-7 Poor--0-3	**9**
Tertiary--Riparian and Bank Structure		
7. Bank Stability	Excellent--9-10 **Good--6-8** Fair--3-5 Poor--0-2	**6**
8. Bank Vegetation	**Excellent--9-10** Good--6-8 Fair--3-5 Poor--0-2	**9**
9. Streamside Cover	Excellent--9-10 Good--6-8 **Fair--3-5** Poor--0-2	**5**
Reference Station: 1=18, 2=18, 3=19, 4=13, 5=13, 6=14, 7=10, 8=10, 9=10		

74/125=59% of high quality reference

Waterbody Name	**Indian Creek and Tributaries**
Location	Indian Creek near Indian Creek Church
Reach/Milepoint	Williams 7.5 min quadrangle; Section 29
County	State--Indiana;
Ecoregion	Eastern Broadleaf Forest; Unglaciated IN
Station Number	Five (5)
Investigators	Baker and Donan Engineering
Date	9/16/98
Time	AM
Agency/Organization	Donan Engineering and DNR Project
Hydrologic Unit Code	
Form Completed By	Baker
Reason For Survey	Bioassessment and Macroinvertebrates
Latitude/Longitude	38.8 approx degrees ; 86.7 approx degrees
Site Descriptors Weather	Partly cloudy; warm
Physical Characterization/Water Quality	Incised creek with surrounding farms and hillsides; exposed bedrock
Riparian Zone/Instream Features	
Predominant Surrounding Land Use Was	**Field and Pasture, Agricultural,** Residential nearby, Commercial, Industrial, **Roads**
Local Watershed Erosion	**None** Moderate Heavy
Nonpoint Sources of Pollution	**Agricultural,** Urban, Feedlots, **Roads,** Septics, Dams, Area modified for communal existence
Stream Width	31' in pools; pool was 28" deep
Velocity in Feet per Second	About 2 feet per second
Average Depth Riffles	<6 inches; shallow with rocks and leaf packs
Cross Sectional Area	
Discharge (Cubic Feet per Second)	Discharge was moderate; <5 cfs
High Water Mark	Almost to top of bank. >10 feet above surface of stream
Dams? Where	Yes **No**
Channelization	None
Canopy Cover	Open Partly Open **Partly Shaded** Shaded
Sediment/Substrate	
Sediment Odors	Sewage Petroleum Chemical Anaerobic

Sediment Oils	**Absent** Slight Moderate Profuse
Sediment Deposits	Sludge Sawdust Fibers Sand Relict Shells Other Muck in pools, **shell midden found--Asiatic clams**
Undersides of rocks black?	Yes **No**
Water Quality Instruments Used: HACH Kit with HACH Conductivity Meter Current Meter	Temperature 22.2 degrees Centigrade Dissolved Oxygen 10.0 mg/L PH 7 Conductivity 0.42 ms/cm Alkalinity 248 mg/L Other
Stream Type	Warm water stream
Water Odors	**Normal** Sewage Petroleum Chemical
Water Surface Oils and Sheen	Slick Sheen Globs Flecks
Turbidity	**Clear** Slightly Turbid Turbid Opaque
Water Color	
Habitat Assessment	
Primary--Substrate and Instream Cover	
1. Bottom Substrate/Available Cover	**Excellent--16-20** **18** Good--11-15 Fair--6-10 Poor--0-5
2. Embeddedness	**Excellent--16-20** **18** Good--11-15 Fair--6-10 Poor--0-5
3. Discharge and Habitats	Excellent--16-20 **Good--11-15** **15** Fair--6-10 Poor--0-5
Secondary--Channel Morphology	
4. Channel Alteration	Excellent--12-15 **Good--8-11** **11** Fair--4-7 Poor--0-3
5. Bottom Scouring and Deposition	Excellent--12-15 **Good--8-11** **10** Fair--4-7 Poor--0-3

6. Pool, Riffle, run bend ratio	Excellent--12-15 **Good--8-11** Fair--4-7 Poor--0-3	**10**
Tertiary--Riparian and Bank Structure		
7. Bank Stability	Excellent--9-10 **Good--6-8** Fair--3-5 Poor--0-2	**8**
8. Bank Vegetation	Excellent--9-10 Good--6-8 **Fair--3-5** Poor--0-2	**5**
9. Streamside Cover	Excellent--9-10 **Good--6-8** Fair--3-5 Poor--0-2	**8**
Reference Station: 1=18, 2=18, 3=19, 4=13, 5=13, 6=14, 7=10, 8=10, 9=10		

103/125=% of high quality reference

Waterbody Name	**Indian Creek and Tributaries**
Location	Spring Creek, a tributary of Indian Creek
Reach/Milepoint	Near Armstrong Station Road in 32 of Owensburg 7.5 min quad
County	State--Indiana; Lawrence Co.
Ecoregion	Eastern Broadleaf Forest; Unglaciated IN
Station Number	Six (6)
Investigators	Baker and Donan Engineering
Date	9/16/98
Time	PM
Agency/Organization	Donan Engineering and DNR Project
Hydrologic Unit Code	
Form Completed By	Baker
Reason For Survey	Bioassessment and Macroinvertebrates
Latitude/Longitude	38.8 approx degrees ; 86.7 approx degrees
Site Descriptors Weather	Partly cloudy; warm
Physical Characterization/Water Quality	Nice creek with alternating riffles and pools
Riparian Zone/Instream Features	
Predominant Surrounding Land Use Was	**Field and Pasture, Agricultural**, Residential nearby, Commercial, Industrial, **Roads**
Local Watershed Erosion	**None** Moderate Heavy
Nonpoint Sources of Pollution	**Agricultural,** Urban, Feedlots, **Roads,** Septics, Dams, **Cows noted in stream above site**
Stream Width	>20 feet; Pool were 18 to 22 inches deep
Velocity in Feet per Second	3.5 to 4 feet per second
Average Depth Riffles	>4 inches; shallow with gravel and leaf packs; riffle was relatively narrow; low flow
Cross Sectional Area	
Discharge (Cubic Feet per Second)	Discharge was moderate; <5 cfs
High Water Mark	None observed
Dams? Where	Yes **No**
Channelization	None
Canopy Cover	Open Partly Open **Partly Shaded** or **Shaded**
Sediment/Substrate	

. Spring Creek, a tributary of Indian Creek. Biomonitoring and Habitat Assessment for the Indian Creek Subwatershed Diagnostic Study.

Sediment Odors	Sewage Petroleum Chemical Anaerobic
Sediment Oils	**Absent** Slight Moderate Profuse
Sediment Deposits	Sludge Sawdust Fibers Sand Relict Shells Other **Muck in pools**
Undersides of rocks black?	Yes **No**
Water Quality Instruments Used: HACH Kit with HACH Conductivity Meter Current Meter	Temperature 22.7 degrees Centigrade Dissolved Oxygen 6.0 mg/L PH 7.5 Conductivity 0.46 ms/cm Alkalinity 212 mg/L Other
Stream Type	Warm water stream
Water Odors	**Normal** Sewage Petroleum Chemical
Water Surface Oils and Sheen	Slick Sheen Globs Flecks
Turbidity	**Clear** Slightly Turbid Turbid Opaque
Water Color	
Habitat Assessment	
Primary--Substrate and Instream Cover	
1. Bottom Substrate/Available Cover	Excellent--16-20 **Good--11-15** **11** Fair--6-10 Poor--0-5
2. Embeddedness	Excellent--16-20 **Good--11-15** **11** Fair--6-10 Poor--0-5
3. Discharge and Habitats	Excellent--16-20 **Good--11-15** **11** Fair--6-10 Poor--0-5
Secondary--Channel Morphology	
4. Channel Alteration	Excellent--12-15 **Good--8-11** **11** Fair--4-7 Poor--0-3
5. Bottom Scouring and Deposition	Excellent--12-15 **Good--8-11** **10** Fair--4-7 Poor--0-3

6. Pool, Riffle, run bend ratio	Excellent--12-15 **Good--8-11** Fair--4-7 Poor--0-3	**10**
Tertiary--Riparian and Bank Structure		
7. Bank Stability	Excellent--9-10 **Good--6-8** Fair--3-5 Poor--0-2	**7**
8. Bank Vegetation	Excellent--9-10 **Good--6-8** Fair--3-5 Poor--0-2	**6**
9. Streamside Cover	Excellent--9-10 **Good--6-8** Fair--3-5 Poor--0-2	**8**
Reference Station: 1=18, 2=18, 3=19, 4=13, 5=13, 6=14, 7=10, 8=10, 9=10		

85/125=68% of high quality reference

Waterbody Name	**Indian Creek and Tributaries**
Location	Town Branch from Owensburg
Reach/Milepoint	Owensburg 7.5 min quad; Section 36
County	State--Indiana; Greene Co.
Ecoregion	Eastern Broadleaf Forest; Unglaciated IN
Station Number	Seven (7)
Investigators	Baker and Donan Engineering
Date	9/16/98
Time	PM
Agency/Organization	Donan Engineering and DNR Project
Hydrologic Unit Code	
Form Completed By	Baker
Reason For Survey	Bioassessment and Macroinvertebrates
Latitude/Longitude	38.8 approx degrees ; 86.7 approx degrees
Site Descriptors Weather	Partly cloudy; warm
Physical Characterization/Water Quality	Small branch
Riparian Zone/Instream Features	
Predominant Surrounding Land Use Was	**Field and Pasture, Agricultural, Residential nearby**, Commercial, Industrial, **Roads**
Local Watershed Erosion	None **Moderate** Heavy
Nonpoint Sources of Pollution	**Agricultural,** Urban, Feedlots, **Roads, Septics**, Dams, **Stream flows through the town of Owensburg**
Stream Width	>20 feet; Pool were 20 inches deep
Velocity in Feet per Second	Very low flow. Riffle was about 12 inches wide
Average Depth Riffles	<2 inches; shallow with gravel and silt
Cross Sectional Area	
Discharge (Cubic Feet per Second)	Discharge was minimal; <1 cfs
High Water Mark	None observed
Dams? Where	Yes **No**
Channelization	None
Canopy Cover	**Open** Partly Open Partly Shaded or Shaded; more shading upstream and downstream
Sediment/Substrate	
Sediment Odors	Sewage Petroleum Chemical Anaerobic

. Town Branch near Owensburg. A tributary of Indian Creek. Biomonitoring and Assessment for the Indian Creek Subwatershed Diagnostic Study.

Sediment Oils	Absent Slight Moderate Profuse
Sediment Deposits	Sludge Sawdust Fibers Sand Relict Shells Other **Muck in pools**
Undersides of rocks black?	Yes **No**
Water Quality Instruments Used: HACH Kit with HACH Conductivity Meter Current Meter	Temperature 24.6 degrees Centigrade Dissolved Oxygen 7.0 mg/L PH 7.5 Conductivity 0.37 ms/cm Alkalinity 159 mg/L Other
Stream Type	Warm water stream
Water Odors	**Normal** Sewage Petroleum Chemical
Water Surface Oils and Sheen	Slick Sheen Globs Flecks Considerable scum and other materials downstream
Turbidity	**Clear** Slightly Turbid Turbid Opaque
Water Color	
Habitat Assessment	
Primary--Substrate and Instream Cover	
1. Bottom Substrate/Available Cover	Excellent--16-20 Good--11-15 **Fair--6-10** **10** Poor--0-5
2. Embeddedness	Excellent--16-20 Good--11-15 **Fair--6-10** **9** Poor--0-5
3. Discharge and Habitats	Excellent--16-20 Good--11-15 **Fair--6-10** **9** Poor--0-5
Secondary--Channel Morphology	
4. Channel Alteration	Excellent--12-15 Good--8-11 **Fair--4-7** **7** Poor--0-3
5. Bottom Scouring and Deposition	Excellent--12-15 **Good--8-11** **10** Fair--4-7 Poor--0-3

6. Pool, Riffle, run bend ratio	Excellent--12-15 Good--8-11 **Fair--4-7** **7** Poor--0-3
Tertiary--Riparian and Bank Structure	
7. Bank Stability	Excellent--9-10 Good--6-8 Fair--3-5 **Poor--0-2** **2**
8. Bank Vegetation	Excellent--9-10 Good--6-8 Fair--3-5 **Poor--0-2** **2**
9. Streamside Cover	Excellent--9-10 Good--6-8 **Fair--3-5** **5** Poor--0-2
Reference Station: 1=18, 2=18, 3=19, 4=13, 5=13, 6=14, 7=10, 8=10, 9=10	

61/125=49% of high quality reference

Waterbody Name	**Indian Creek and Tributaries**
Location	Popcorn Creek
Reach/Milepoint	Owensburg 7.5 min quad; Section 8
County	State--Indiana; Lawrence Co.
Ecoregion	Eastern Broadleaf Forest; Unglaciated IN
Station Number	Eight (8)
Investigators	Baker and Donan Engineering
Date	9/16/98
Time	PM
Agency/Organization	Donan Engineering and DNR Project
Hydrologic Unit Code	
Form Completed By	Baker
Reason For Survey	Bioassessment and Macroinvertebrates
Latitude/Longitude	38.8 approx degrees ; 86.7 approx degrees
Site Descriptors Weather	Partly cloudy; warm
Physical Characterization/Water Quality	Adequate stream in limestone area
Riparian Zone/Instream Features	
Predominant Surrounding Land Use Was	**Field and Pasture, Agricultural,** Residential nearby, Commercial, Industrial, **Roads**
Local Watershed Erosion	None **Some from Fields** Moderate Heavy
Nonpoint Sources of Pollution	**Agricultural,** Urban, Feedlots**, Roads,** Septics, Dams,
Stream Width	>41' 9" feet; Pools were 14 to 24 inches deep
Velocity in Feet per Second	Low flow. Riffle was about 4 feet wide
Average Depth Riffles	<2 inches; shallow with bedrock and silt
Cross Sectional Area	
Discharge (Cubic Feet per Second)	Discharge was minimal; <1 cfs
High Water Mark	Debris in tree above pool; about 6 feet above surface.
Dams? Where	Yes **No**
Channelization	None
Canopy Cover	**Open** Partly Open Partly Shaded or Shaded; Shading downstream.
Sediment/Substrate	
Sediment Odors	Sewage Petroleum Chemical Anaerobic

Sediment Oils	**Absent** Slight Moderate Profuse
Sediment Deposits	Sludge Sawdust Fibers Sand Relict Shells Other **Muck in pools**
Undersides of rocks black?	Yes **No**
Water Quality Instruments Used: HACH Kit with HACH Conductivity Meter Current Meter	Temperature 24.2 degrees Centigrade Dissolved Oxygen 9.0 mg/L PH 7.5 Conductivity 0.48 ms/cm Alkalinity 283 mg/L Other
Stream Type	Warm water stream
Water Odors	**Normal** Sewage Petroleum Chemical
Water Surface Oils and Sheen	Slick Sheen Globs Flecks
Turbidity	**Clear** Slightly Turbid Turbid Opaque
Water Color	
Habitat Assessment	
Primary--Substrate and Instream Cover	
1. Bottom Substrate/Available Cover	Excellent--16-20 Good--11-15 **Fair--6-10** **10** Poor--0-5
2. Embeddedness	Excellent--16-20 **Good--11-15** **15** Fair--6-10 Poor--0-5
3. Discharge and Habitats	Excellent--16-20 Good--11-15 **Fair--6-10** **10** Poor--0-5
Secondary--Channel Morphology	
4. Channel Alteration	**Excellent--12-15** **12** Good--8-11 Fair--4-7 Poor--0-3
5. Bottom Scouring and Deposition	Excellent--12-15 **Good--8-11** **11** Fair--4-7 Poor--0-3
6. Pool, Riffle, run bend ratio	Excellent--12-15 **Good--8-11** **8** Fair--4-7 Poor--0-3

Tertiary--Riparian and Bank Structure	
7. Bank Stability	**Excellent--9-10** **9** Good--6-8 Fair--3-5
8. Bank Vegetation	**Excellent--9-10** **9** Good--6-8 Fair--3-5 Poor--0-2
9. Streamside Cover	Excellent--9-10 Good--6-8 **Fair--3-5** **5** Poor--0-2
Reference Station: 1=18, 2=18, 3=19, 4=13, 5=13, 6=14, 7=10, 8=10, 9=10	

89/125=71% of high quality reference

Waterbody Name	**Indian Creek and Tributaries**
Location	Little Indian Creek
Reach/Milepoint	Stanford 7.5 min quad
County	State--Indiana; Greene Co.
Ecoregion	Eastern Broadleaf Forest; Unglaciated IN
Station Number	Nine (9)
Investigators	Baker and Donan Engineering
Date	9/16/98
Time	PM
Agency/Organization	Donan Engineering and DNR Project
Hydrologic Unit Code	
Form Completed By	Baker
Reason For Survey	Bioassessment and Macroinvertebrates
Latitude/Longitude	39 approx degrees ; 86.7 approx degrees
Site Descriptors Weather	Raining lightly; warm
Physical Characterization/Water Quality	Nice stream in agricultural area; some relief apparent
Riparian Zone/Instream Features	
Predominant Surrounding Land Use Was	**Field and Pasture, Agricultural**, Residential nearby, Commercial, Industrial, **Roads**
Local Watershed Erosion	None **Some from Fields** Moderate Heavy
Nonpoint Sources of Pollution	**Agricultural,** Urban, Feedlots**, Roads**, Septics, Dams,
Stream Width	37' 3" in pool; Pools were 22 to 30 inches deep
Velocity in Feet per Second	Low flow. Riffle was about 4 feet wide
Average Depth Riffles	<2 inches; shallow with gravel and smaller slabs--some embedded in silt
Cross Sectional Area	
Discharge (Cubic Feet per Second)	Discharge was minimal; <2 cfs
High Water Mark	None observed
Dams? Where	Yes **No**
Channelization	None
Canopy Cover	Open Partly Open **Partly Shaded or Shaded**; Shading downstream.
Sediment/Substrate	
Sediment Odors	Sewage Petroleum Chemical Anaerobic

Sediment Oils	**Absent** Slight Moderate Profuse
Sediment Deposits	Sludge Sawdust Fibers Sand Relict Shells Other **Some sediment in the pools**
Undersides of rocks black?	Yes **No**
Water Quality Instruments Used: HACH Kit with HACH Conductivity Meter Current Meter	Temperature 22.3 degrees Centigrade Dissolved Oxygen 9.0 mg/L PH 7.5 Conductivity 0.44 ms/cm Alkalinity 177 mg/L Other
Stream Type	Warm water stream
Water Odors	**Normal** Sewage Petroleum Chemical
Water Surface Oils and Sheen	Slick Sheen Globs Flecks
Turbidity	**Clear** Slightly Turbid Turbid Opaque
Water Color	
Habitat Assessment	
Primary--Substrate and Instream Cover	
1. Bottom Substrate/Available Cover	Excellent--16-20 **Good--11-15** **11** Fair--6-10 Poor--0-5
2. Embeddedness	Excellent--16-20 **Good--11-15** **11** Fair--6-10 Poor--0-5
3. Discharge and Habitats	Excellent--16-20 **Good--11-15** **11** Fair--6-10 Poor--0-5
Secondary--Channel Morphology	
4. Channel Alteration	Excellent--12-15 **Good--8-11** **11** Fair--4-7 Poor--0-3
5. Bottom Scouring and Deposition	Excellent--12-15 **Good--8-11** **11** Fair--4-7 Poor--0-3
6. Pool, Riffle, run bend ratio	Excellent--12-15 **Good--8-11** **8** Fair--4-7 Poor--0-3

Tertiary--Riparian and Bank Structure		
7. Bank Stability	Excellent--9-10 **Good--6-8** Fair--3-5	**8**
8. Bank Vegetation	**Excellent--9-10** Good--6-8 Fair--3-5 Poor--0-2	**9**
9. Streamside Cover	Excellent--9-10 **Good--6-8** Fair--3-5 Poor--0-2	**8**
Reference Station: 1=18, 2=18, 3=19, 4=13, 5=13, 6=14, 7=10, 8=10, 9=10		

88/125=70% of high quality reference

Waterbody Name	**Indian Creek and Tributaries**
Location	Indian Creek
Reach/Milepoint	Stanford 7.5 min quad
County	State--Indiana; Monroe Co.
Ecoregion	Eastern Broadleaf Forest; Unglaciated IN
Station Number	Ten (10)
Investigators	Baker and Donan Engineering
Date	9/16/98
Time	PM
Agency/Organization	Donan Engineering and DNR Project
Hydrologic Unit Code	
Form Completed By	Baker
Reason For Survey	Bioassessment and Macroinvertebrates
Latitude/Longitude	39 approx degrees ; 86.7 approx degrees
Site Descriptors Weather	Partly cloudy; warm
Physical Characterization/Water Quality	Incised stream in agricultural and wooded area
Riparian Zone/Instream Features	
Predominant Surrounding Land Use Was	**Field and Pasture, Agricultural, Wooded Hillside**, Residential nearby, Commercial, Industrial, **Roads**
Local Watershed Erosion	None **Some from Fields** Moderate Heavy
Nonpoint Sources of Pollution	**Agricultural,** Urban, Feedlots**, Roads,** Septics, Dams,
Stream Width	Wide, shallow pools 25+" feet; Pools were 6 to 30 inches deep
Velocity in Feet per Second	Low flow. Riffle was about 6 feet wide
Average Depth Riffles	<2 inches; shallow with sandstone bedrock, smaller boulders and silt
Cross Sectional Area	
Discharge (Cubic Feet per Second)	Discharge was minimal; <2 cfs
High Water Mark	None observed
Dams? Where	Yes **No**
Channelization	None
Canopy Cover	Open Partly Open **Partly Shaded** or **Shaded**; Substantial shading upstream.
Sediment/Substrate	
Sediment Odors	Sewage Petroleum Chemical Anaerobic

Sediment Oils	**Absent** Slight Moderate Profuse
Sediment Deposits	Sludge Sawdust Fibers Sand Relict Shells Other **Silt in pools**
Undersides of rocks black?	Yes **No**
Water Quality Instruments Used: HACH Kit with HACH Conductivity Meter Current Meter	Temperature 22.6 degrees Centigrade Dissolved Oxygen 8.0 mg/L PH 7.5 Conductivity 0.39 ms/cm Alkalinity 177 mg/L Other
Stream Type	Warm water stream
Water Odors	**Normal** Sewage Petroleum Chemical
Water Surface Oils and Sheen	Slick Sheen Globs Flecks
Turbidity	**Clear** Slightly Turbid Turbid Opaque
Water Color	
Habitat Assessment	
Primary--Substrate and Instream Cover	
1. Bottom Substrate/Available Cover	Excellent--16-20 Good--11-15 **Fair--6-10** **10** Poor--0-5
2. Embeddedness	Excellent--16-20 **Good--11-15** **15** Fair--6-10 Poor--0-5
3. Discharge and Habitats	Excellent--16-20 Good--11-15 **Fair--6-10** **10** Poor--0-5
Secondary--Channel Morphology	
4. Channel Alteration	Excellent--12-15 **Good--8-11** **11** Fair--4-7 Poor--0-3
5. Bottom Scouring and Deposition	**Excellent--12-15** **12** Good--8-11 Fair--4-7 Poor--0-3
6. Pool, Riffle, run bend ratio	Excellent--12-15 **Good--8-11** **9** Fair--4-7 Poor--0-3

Tertiary--Riparian and Bank Structure		
7. Bank Stability	**Excellent--9-10** Good--6-8 Fair--3-5	**10**
8. Bank Vegetation	**Excellent--9-10** Good--6-8 Fair--3-5 Poor--0-2	**9**
9. Streamside Cover	Excellent--9-10 **Good--6-8** Fair--3-5 Poor--0-2	**7**
Reference Station: 1=18, 2=18, 3=19, 4=13, 5=13, 6=14, 7=10, 8=10, 9=10		

93/125=74% of high quality reference

APPENDIX E

Aquatic Macroinvertebrate Families

APPENDIX 4

Aquatic Macroinvertebrate Families Taken from Indian Creek in 1998

Organism	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	Station 7	Station 8	Station 9	Station 10
Name	1,2,3,Q	1,2,3, Q	1,2,3, Q	1,2,3, Q	1,2,3, Q	1,2,3, Q	1,2,3, Q	1,2,3, Q	1,2,3, Q	1,2,3, Q
Phylum Mollusca										
Class Gastropoda										
Family Physidae	2,1,1,1				--,1,--,--			1,--,--,--		
Fam. Planorbidae	7,--,--,--				1,--,--,--					
Fam. Pleurocercidae	7,9,3,0	9,11,9	1,--, --, 7	5,8,3,5	5,2,3,9	7,3, --,1	--,--,2,--		5,--,--,1	14,--,4,--
Class Pelycypoda										
Fam. Corbiculidae	18,6,1,Q	4,6,2,Q		6,4,3	7,3,1,Q					
Phylum Annelida										
Class Hirudinea					1Q					--,1,--,--
Phylum Arthropoda										
Class Arachnida						3,--,--,--				
Order Isopoda										
Fam. Aselliidae		57,45,35	2,--,--,--		26,30,6		1,--,--,--	1,2,2,1	6,--,--,6	3,--,5,6
Order Amphipoda										
Fam. Talitridae		3,1,0,--		--,--,1	1,--,3,--		1,--,4,1	--,3,2,--	4,--,--,--	5Q
Class Crustacea										
Order Decapoda										
Family Astacidae				--,--,--,1	--,1,--,--	1Q	--,1,--,1		1,--,--,2	1Q
Classr Insecta										
Order Collembola										
Fam. Isotomidae	0,0,1,2									

Order Megaloptera										
Family Sialidae		3,2,--,--			1,1,--,--					
Family Corydalidae		2,1,1		--,--,--,1	Qual.	--,1,--,--	2,6,7,2		1,--,--,--	--,--,1,1Q
Order Ephemeroptera										
Fam. Baetidae	15,--,4,--	23,16,7	9,--,--,--		--,3,34,1	17,22,7	5,--,--,--			7,--,--,--
Fam. Heptageniidae	--,1,--,9	29,29,36	30,--,1,--		--,14,16,5	25,7,3,--	1,1,--,--	1,--,--,--	12,7Q	2Q
Fam. Leptophlebiidae			8,--,--,--		1,--,--,--					
Fam. Ephemeridae			1,--,--,--		2,--,--,--					
Fam. Caenidae	4,--,1,2									
Fam. Isonychiidae						12,10,5	9,19,61, 16Q	1,--,--,--	--,2,--,--	5,--,2,1Q
Order Odonata										
Fam. Gomphidae	8,1,3,0							1,--,--,--		
Fam. Libellulidae	1,--,--,--									
Fam. Coenagrionidae		--,--,1		1,--,--,--			3,2,--,--			
Order Hemiptera										
Fam. Belostomatidae				1Q						
Fam. Veliidae		1,--,--,--								
Fam. Mesoveliidae							--,--,1,--			
Order Plecoptera										
Fam. Perlidae					2,4,2,1		1,1,4,1	--,--,--,1	--,1,--,2Q	

Order Tricoptera										
Fam. Philopotamidae					--,--,1	1,36,51	10,7,11,2	--,7,8	--,2	9,--,7,--
Fam. Hydropsychidae	5,--,--,--	4,3,--,--		--,--,1	--,--,27	96,76,31,--	16,19,11,12	13,22,12	12,9,0,9	14,--,14,16
Order Coleoptera										
Fam. Dytiscidae		1,0,0,--								
Fam. Hydrophilidae	--,1,4,--			--,--,--,1				1,1,2,1		
Fam. Elmidae.	--,--,--,1	5,9,5	8,--,--,--	7,2,--,--	7,15,2	17,10,1	4,15,9,10	--,9,--,--	11,15,--,2	17,--,20,6
Fam. Psephenidae		0,1,0				8,4,12	23,10,9,17	--,--,1	7,6,--,6	10,--,7,3
Fam. Dryopidae	--,--,--,3					5,11,10,6				
Order Diptera										
Fam Tipulidae.		6,5,2,--		1,1,--,--		58,15,18,1	8,5,4	1,2,--,--	3,--,3	--,3,3,--
Fam. Simuliidae					--,--,14	1,--,--,--				
Fam. Chironomidae	116,29,76,11	21,23,31	9,--,2,--	1,--,--,--	11,5,122, 19	53,--,--,26	24,7,26	67,89,52, 5	1,--,11,--	1Q
Fam. Stratiomyidae	2,6,--									
Fam. Tabanidae		4,--,--		1,--,--,--		1,--,--,--	--,--,4,1Q		--,1,--,--	
Fish								1Q		
Larval Salamanders							--,--,1,--			
Total N	358	453	78	66	409	672	412	310	148	186
Taxa Richness	16	17	8	16	18	16	19	15	15	16

Notes:

APPENDIX F

Sampling Site Photographs

Site 1. Opossum Creek Tributary of Indian Creek.
The Indian Creek Study: Donan Engineering and
Indiana University Southeast. 1999
Downstream

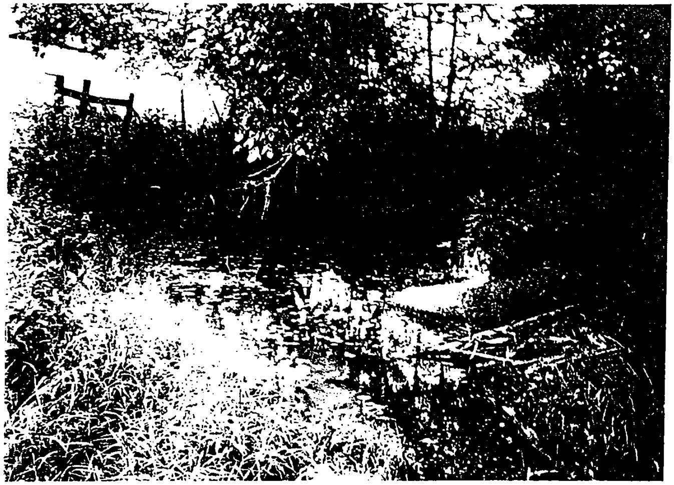
Site 1. Opossum Creek Tributary of Indian Creek.
The Indian Creek Study: Donan Engineering and
Indiana University Southeast. 1999
Field to Right Looking Upstream

Site 2. Sulphur Creek. Tributary of Indian Creek.
The Indian Creek Study: Donan Engineering and
Indiana University Southeast. 1999
Downstream Riffle

Site 2. Sulphur Creek. Tributary of Indian Creek.
The Indian Creek Study: Donan Engineering and
Indiana University Southeast. 1999
Upstream--Bridge in background

Site 3. Indian Creek Downstream.
The Indian Creek Study: Donan Engineering and
Indiana University Southeast. 1999
Riffle-run Area with Log Jam

Site 3. Indian Creek Downstream.
The Indian Creek Study: Donan Engineering and
Indiana University Southeast. 1999
Upstream



Site 4. Padanaram. The Indian Creek Study: Donan Engineering and Indiana University Southeast. 1999. Downstream from Riffle. Note Culvert in Water.

Site 4. Padanaram. The Indian Creek Study: Donan Engineering and Indiana University Southeast. 1999. Upstream with Typical Lodge in the Background.

Site 5. Indian Creek near Indian Creek Church. The Indian Creek Study: Donan Engineering and Indiana University Southeast. 1999. Downstream with Bridge.

Site 5. Indian Creek near Indian Creek Church. The Indian Creek Study: Donan Engineering and Indiana University Southeast. 1999. Riffle.

Site 6. Spring Creek.Tributary of Indian Creek. The Indian Creek Study: Donan Engineering and Indiana University Southeast. 1999. Riffle and Downstream. Beneath Existing Bridge.

Site 6. Spring Creek.Tributary of Indian Creek. The Indian Creek Study: Donan Engineering and Indiana University Southeast. 1999. Upstream.

Site 7. Town Branch Tributary of Indian Creek. The Indian Creek Study: Donan Engineering and Indiana University Southeast. 1999. Upstream with Riffle Area in Foreground.

Site 7. Town Branch.Tributary of Indian Creek. The Indian Creek Study: Donan Engineering and Indiana University Southeast. 1999. Bank Erosion.

Site 8. Popcorn Creek Tributary of Indian Creek. The Indian Creek Study: Donan Engineering and Indiana University Southeast. 1999. Riffle Area over Bedrock.

Site 8. Popcorn Creek Tributary of Indian Creek. The Indian Creek Study: Donan Engineering and Indiana University Southeast. 1999. Upstream. Bridge in the Background.

Site 9. Little Indian Creek. The Indian Creek Study: Donan Engineering and Indiana University Southeast. 1999. Downstream. Bridge in the Background.

Site 9. Little Indian Creek Tributary of Indian Creek. The Indian Creek Study: Donan Engineering and Indiana University Southeast. 1999. Upstream.

Site 10. Indian Creek. The Indian Creek Study: Donan Engineering and Indiana University Southeast. 1999. Downstream.

Site 10. Indian Creek The Indian Creek Study: Donan Engineering and Indiana University Southeast. 1999. Upstream. Bridge in the Background.

APPENDIX G

Eroded Streambank Repair Methods

ERODED STREAMBANK REPAIR

Practice 501	Live Stakes
Practice 502	Live Fascines
Practice 503	Branch Packings
Practice 504	Tree Revetments
Practice 505	Brush Mattress
Practice 506	Vegetative Geogrids
Practice 507	Live Cribwalls
Practice 508	Lunkers
Practice 509	A-Jacks
Practice 510	Stone Riprap
Practice 511	Concrete Retaining Wall
Practice 512	Gabion Retaining Wall
Practice 513	Timber Retaining Wall
Practice 514	Sheetpile Retaining Wall
Practice 515	Composite Retaining Wall

ERODED STREAMBANK REPAIR

Stream channel erosion can generally be corrected using either vegetative (Practices 501-506) or structural (Practices 510-515) techniques, or a combination of both (practices 507-509 and other possible combinations). Vegetation techniques are generally less expensive than structural, and are generally more compatible with stream characteristics. Structural techniques, though expensive and considered unsightly by some, may offer more permanent protection against erosion. Regardless of which technique the Handbook user decides to utilize, it is important to keep in mind that no one measure works well in all situations.

The following methods are described in terms of cost, applicability, ease of installation, and the advantage of using one technique over another. This list is not comprehensive, nor is it attempted to anticipate all circumstances in which one method might be used over another. Thus, the users must decide for themselves which method best fits the character of their particular location and problem.

Vegetative methods tend to work well along natural streams, in urban areas where a natural appearance, improved habitat, and water quality is important, and where cost may be a deciding factor as to whether a stream is restored. Visually, streams repaired using vegetative methods may take on a natural appearance after only one growing season. The network of plants critical to all vegetative techniques absorbs erosional energy during floods, provides habitat for wildlife, acts as a barrier to ice scour, conserves soil moisture, and stabilizes the soils and streambank.

Choosing a vegetative technique depends largely upon the type of problem encountered. Moderately eroded stream banks may be repaired with minimum regrading, and the installation of live stakes, a seed mix, and mulch. Live fascines, branch packings, and brush mattresses might be employed in areas with more serious erosion problems, but where there is still at least a 2:1 (1V:2H) grade to work with. However, note that the toe of slope may still require structural stabilization. Live cribwalls, lunkers, A-jacks, and vegetative geogrids work well in severely eroded areas with steep banks.

Structural techniques may be considered in highly developed areas with little to no natural overbank or where streambank pedestrian traffic is heavy. Retaining walls are generally preferred for steep to sheer, unprotected streambanks. Sheet piling may be preferred in areas where aesthetics are not important, and where space limitations prohibits the construction of a timber or concrete wall. All structural techniques should be installed in accordance with the manufacturer's specifications. Improper installation of these techniques can exacerbate erosion problems by transferring and amplifying stream velocity downstream.

Many of these techniques can and should be combined either for enhanced structural stability, improved environmental quality, or for a more aesthetically pleasing appearance. Top soil and live stakes can be placed between gabion baskets to create a more natural appearance. Riprap is sometimes advised along the eroded toe of a slope after which vegetative techniques can be used for the remainder of the slope.

Large-scale stabilization projects should be planned and designed by an experienced engineer or stream restorationist. Detailed stream studies are advised prior to tackling long, stream channel reaches. The U.S. Army Corps of Engineers' Waterways Experiment Station - Streambank Protection Guidelines for Landowners and Local Governments is one recommended reference for the engineering of major stabilization projects.

PRACTICE 501
LIVE STAKES

DESCRIPTION

- Live shrub or woody plant cuttings driven into the channel bank as stakes.

Exhibit 501a: Live Stakes (Source: NRCS Engineering Field Handbook)

PURPOSE

- To protect streambanks from the erosive forces of flowing water and to stabilize the soils along the channel bank

WHERE APPLICABLE

- Along streambanks of moderate slope, usually 4:1 or less.
- Applicable in original bank soil, not on fill.
- Useful where active erosion is light and washout is not likely.
- Often applicable in combination with other vegetative or structural stabilization methods.
- Applicable on all sizes of channels and all character types.

ADVANTAGES

- Economical, especially when cuttings are available locally.
- Can be done quickly with minimum labor.
- Results in a permanent, natural installation.
- Improved riparian habitat

CONSTRAINTS

- Should be combined with other techniques such as vegetative stabilization (Practice 1102) or mulching (Practice 1101).
- Does not provide initial surface protection until top growth has occurred.
- Will be ineffective in areas of active erosion or on channels with high fluctuation of flows.

DESIGN AND CONSTRUCTION GUIDELINES

Materials

- Cuttings should be 24 - 30 inches long and ½ - 1½ inches in diameter.
- Live cuttings with side branches cleanly removed and bark intact.

- The larger of thicker butt-ends should be cleanly cut at a 45 degree angle for easy insertion into the soil and the top should be cut square or blunt.
- Cuttings should have at least 2 bud scars near the top to facilitate development of branches.
- Cuttings must be fresh and kept moist. After they have been prepared into appropriate lengths, they should not be stored for more than 1 day before driving into the soil. To increase their rate of survival they should be placed the same day.

Installation

- Starting at the lower level, drive the cuttings into the bank at right angles to the slope. (A live fascine incorporated at the low water level will add stability to the toe of the slope. See Practice 502.)
- 4/5 of the length of the cutting should be driven into the ground and the soil should be firmly packed around the cutting.

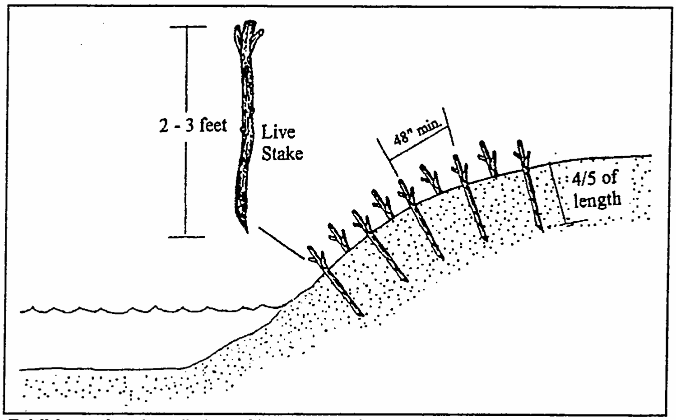


Exhibit 501b: Installation of live stakes (Source: DuPage County Streambank Stabilization Program)

- Do not split the cuttings during insertion.
- An iron bar can be used to make the hole.
- The density of the installation depends on the site conditions, ranging from 2 - 6 cuttings per square yard. A spacing of 2 feet or greater is recommended.
- The stakes should be placed in off center rows.

Special Considerations

- Harvest live stakes during dormant season.
- Store live stakes under cold water (lake, stream, pond) for up to 3 days before installation.
- May need to fortify toe of slope (eg. fiber roll).
- Bank grading may be required to achieve moderate slopes before installation.

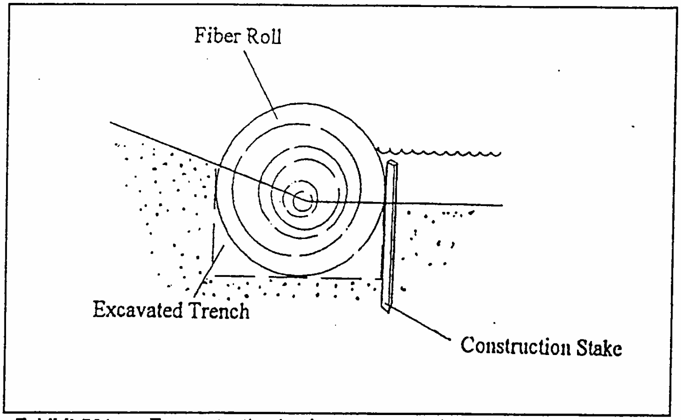


Exhibit 501c: Toe protection is often recommended when using live stakes (Source: DuPage County Streambank Stabilization Program)

MAINTENANCE

- Vegetated channel banks are vulnerable to new damage, especially right after installation. Inspect after highwater events for gaps in cover and repair with new plants. Mulch/seed exposed areas if necessary.

REFERENCES

Related Practices

- Practice 502 Live Fascines.
- Practice 503 Branch Packings.
- Practice 505 Brush Mattress.

Other Sources of Information

- Pennsylvania Streambank Stabilization Guide.
- North Carolina Erosion Control Manual.
- Tennessee Riparian Restoration Handbook.
- Iowa Streambank Erosion Control.
- DuPage County Streambank Erosion Control Handbook

PRACTICE 502
LIVE FASCINES

DESCRIPTION

- Sausage-shaped bundles of brush tied together, and placed in trenches cut into the bank, parallel to the stream.

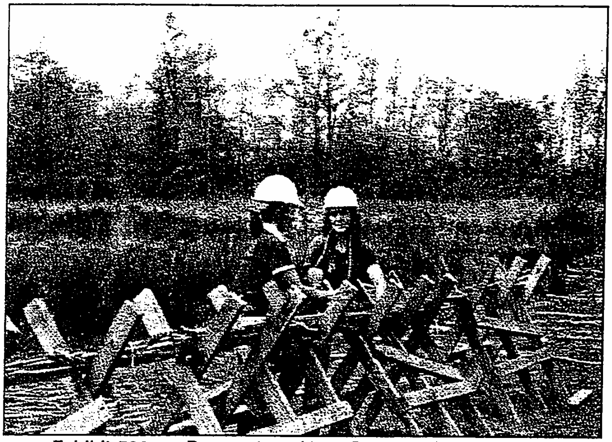


Exhibit 502a: Preparation of Live Fascines (Source: NRCS Engineering Field Handbook)

PURPOSE

- To protect banks from washout and seepage, particularly at the edge of a stream, and where water levels fluctuate moderately.

WHERE APPLICABLE

- Effective with any stream type or size.
- Approximately 1:1 (1V:1H) slopes or flatter.
- Toe of bank and up slope area.
- Straight or curved sections.

ADVANTAGES

- Immediate erosion protection.
- Traps sediment.
- Reduces gullying.
- Slows surface water flows and increases infiltration on draughty sites.
- Provides surface stability for the establishment of vegetation.
- Improves riparian habitat

CONSTRAINTS

- Labor intensive.
- Vegetative stabilization needed between fascines.
- Construction must occur during dormant season.
- Not recommended in areas with high surface drainage over bank.

DESIGN AND CONSTRUCTION GUIDELINES

Materials

- Cuttings should be > 4' long and < 1" in diameter from a variety of species that root easily, and have long, straight branches, such as willows (See Practice 501 Live Stakes).

- Jute rope.
- 3' oak construction stakes or live stakes.
- Vegetative Stabilization (Practice 1102).

Installation

- Drive stakes in a row across the slope beginning at the base of the bank at mean low water level. Stakes should be 12"-18" on center so 6" remain above the grade.
- Assemble bundles in 8"-10" diameter rolls in lengths of 1- 1½" longer than the maximum stem length by alternating stems, tapering ends, and securing with a jute rope.
- Dig a shallow trench as deep as the diameter of the fascine. Trenching should not precede placement of the bundles by more than one hour to minimize drying of soils.
- Lay bundles in trench, overlapping tapered ends.
- Drive live stakes or construction stakes through bundle, 12" on center, with additional stakes at joints.

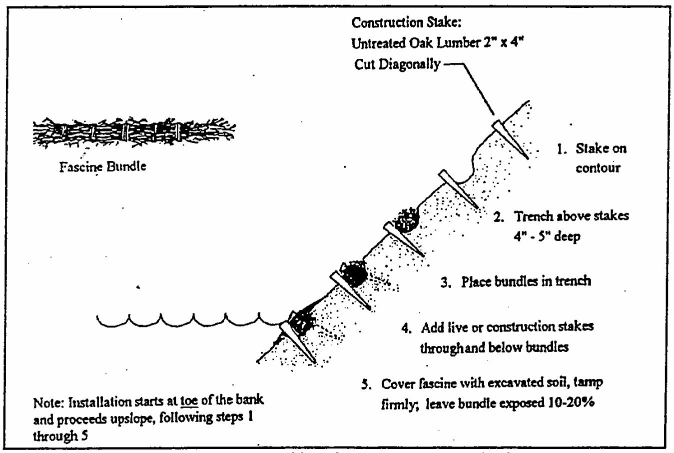


Exhibit 502b: Installation of live fascines (Source: DuPage County Streambank Stabilization Program)

- Cover fascines with excavated soil, tamping to fill voids, but leaving 10-20% of the bundles exposed.
- Eliminate air by walking on bundles.
- Continue rows to top of bank, spacing fascines according to table below (Exhibit 502c).

Slope	Slope distance between trenches (ft)	Maximum slope length (ft)
1:1 (1V:1H) to 1.5:1 (1V:1.5H)	3 - 4	15
1.5:1 (1V:1.5H) to 2:1 (1V:2H)	4 - 5	20
2:1 (1V:2H) to 2.5:1 (1V:2.5H)	5 - 6	30
2.5:1 (1V:2.5H) to 3:1 (1V:3H)	6 - 8	40
3:1 (1V:3H) to 4:1 (1V:4H)	8 - 9	50
4:1 (1V:4H) to 5:1 (1V:5H)	9 - 10	60

Exhibit 502c: Distance between fascines based on bank slope length and grade.

- Revegetate disturbed area between fascines according to vegetative stabilization method.

Special Considerations

- Make sure there is sufficient contact between soil and fascines.
- Additional toe protection may be needed in high velocity areas.
- Store cut brush under cold water (lake, stream, pond) for up to three days before installation.

MAINTENANCE

- Low. Monitor for washouts. Follow maintenance for vegetative stabilization.

REFERENCES

Related Practices

- Practice 501 Live Stakes.
- Practice 503 Branch Packings.
- Practice 505 Brush Mattress.

Other Sources of Information

- Pennsylvania Streambank Stabilization Guide.
- Tennessee Riparian Restoration Handbook.
- Iowa Streambank Erosion Control.
- DuPage County Streambank Stabilization Program.
- NRCS Engineering Field Handbook.

PRACTICE 503
BRANCH PACKINGS

DESCRIPTION

- Alternating layers of branches and soil incorporated into a hole or slumped out area in a slope or a streambank. Branches are used both underwater and above. The branches above the water line root to form a permanent installation while those below the water line provide initial stability.

Exhibit 503a: Branch Packings (Source: NRCS Engineering Field Handbook)

PURPOSE

- To repair washouts and scoured holes.

WHERE APPLICABLE

- Particularly useful method for banks that have had washouts.
- Applicable even where water is fast and moderately deep.
- Washout or hole should be no more than 12' long, 5' wide, and 4' deep.

ADVANTAGES

- Creates an immediate barrier, redirecting water away from the washed out area.
- Cuttings normally available locally.
- Produces immediate filter barrier.
- Useful in fast moving water.
- Permanent and natural appearance.
- Improved riparian habitat

CONSTRAINTS

- Large amounts of branches required.
- Very labor intensive.

DESIGN AND CONSTRUCTION GUIDELINES

Materials

- Live cuttings which readily root. Cuttings may be 0.5" to 3" in diameter and long enough to reach the original bank soil with 12" left exposed on the stream side.

- Stakes 6' to 8' long.
- Large rocks, soil and gravel.

Installation

- Starting below the low water line, drive stakes vertically into the soil, 3' apart.
- Place a 3" - 4" layer of compressed branches in the bottom of the washout, between the vertical stakes. Cover branch mat with 8" to 12" of soil and gravel. Rocks large enough to resist the current may be placed on top of the branch mat from the stream bottom up to the average water level.
- Layers of branches are installed with the basal ends angled down into the streambank so that they are at least 12" lower than the tips of the branches.
- Follow each layer of branches with a soil and gravel mix. Compact thoroughly to insure soil contact with branch cuttings.
- Successive layers of branches and fill are alternated until the washout is completely filled.
- Branch tips must extend beyond the soil layers to grow. Basal ends must extend into undisturbed soil.

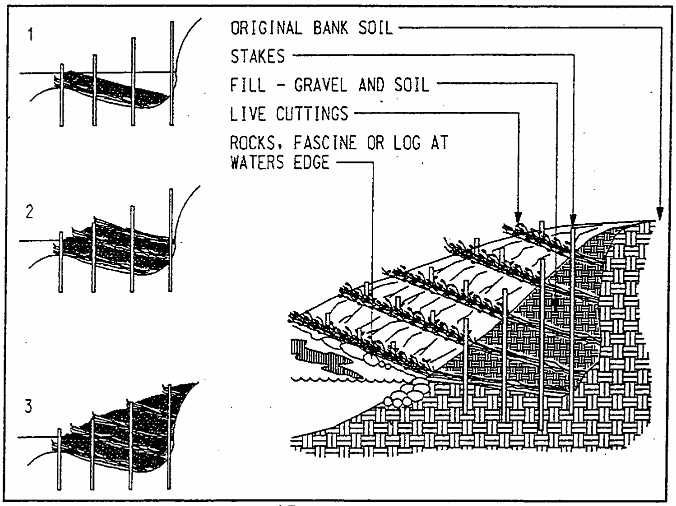


Exhibit 503b: Installation of Branch Packings (Source: CBBEL Files)

Special Considerations

- Make sure there is sufficient contact between soil and live cuttings.
- Rocks, fascine, or a log may be placed at water's edge.
- Branch packings should not be constructed over 5' in height (including the footing), and no more than 10' in length, without the assistance of a knowledgeable professional.

MAINTENANCE

- Low. Monitor and repair as necessary.

REFERENCES

Related Practices

- Practice 502 Live Fascines.
- Practice 509 A-Jacks.
- Practice 510 Stone Riprap.

Other Sources of Information

- Pennsylvania Streambank Stabilization Guide.
- Soil Bioengineering Strategies.

PRACTICE 504
TREE REVETMENTS

DESCRIPTION
- Anchoring dead, cut trees along an eroding streambank to control erosion.

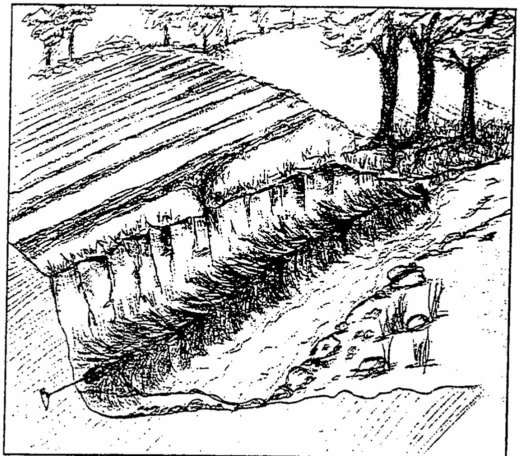


Exhibit 504a: Tree Revetments (Source: Watershed Council Shoreline Erosion Guidebook)

PURPOSE
- To slow the current along eroding banks and cause desirable deposition of silt, sand, and gravel.

WHERE APPLICABLE
- On bends of small to medium sized streams where original cover has been removed.

ADVANTAGES
- Inexpensive.
- Easy to install.
- Materials readily available.
- Provides aquatic and wildlife habitat.

CONSTRAINTS
- Only recommended for small to medium sized streams with minimal to moderate erosion problems.
- Not recommended for highly unstable streams or channels.
- Should not be used if the eroding stream bank is over 12' high.
- Not recommended if the toe is more than 2.5' below the NWL.

DESIGN AND CONSTRUCTION GUIDELINES

Materials
- Large, live trees (evergreens work best).
- Driven earth anchors or steel fence posts.
- Cable (3/16" aircraft cable or larger) and cable clamps.

Installation
- The first tree revetment should be placed at the downstream end of the eroding bank, with the butt-end pointed upstream.

- Anchor both ends of each revetment tightly against the toe of the bank using earth anchors or steel fence posts, and aircraft cable.
- Each subsequent revetment should overlap the prior revetment in a fishscale pattern, and anchored as described earlier.

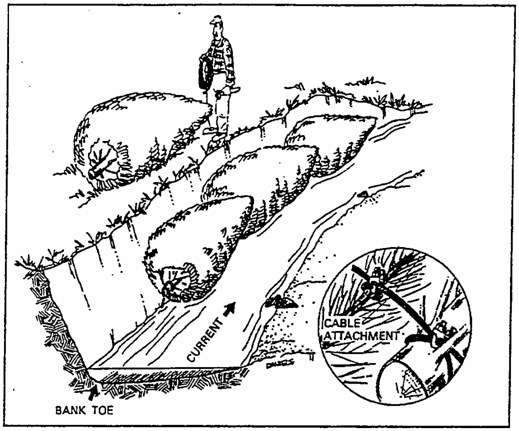


Exhibit 504b: Installation of tree revetments (Source: Missouri Tree Revetments)

Special Considerations

- Live, cut trees work better than dead trees because they are more flexible, and last longer.
- Evergreens are preferred over hardwoods because of the conical shape of evergreens, and dense branches and needles.
- Large trees are preferred over small trees.
- Cedar trees placed in early summer can dry out and lose their needles, thus reducing their ability to trap sediment and slow water flow.
- Revetments may be fortified with other vegetative techniques once enough silt has been deposited to support a seed bed or live stakes.

MAINTENANCE

- Revetments should be inspected following flood events and repaired as necessary.

REFERENCES

Related Practices

- Practice 501 Live Stakes.
- Practice 502 Live Fascines.
- Practice 503 Branch Packings.
- Practice 505 Brush Mattress.

Other Sources of Information

- Missouri Tree Revetments.
- Watershed Council Shoreline Erosion Guidebook.
- Stream Habitat Improvement Handbook.

PRACTICE 505
BRUSH MATTRESS

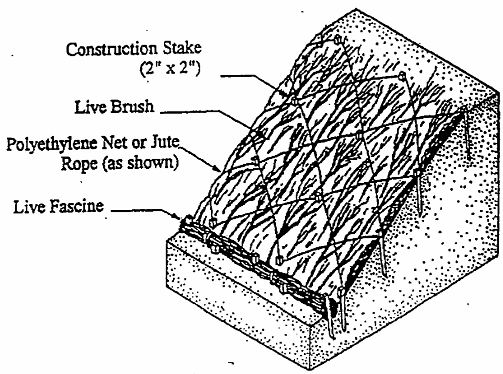
DESCRIPTION	•	Mat of live brush fastened down over an eroded bank.

Exhibit 505a: Brush Mattress (Source: NRCS files)

PURPOSE	•	Erosion protection; rebuilds banks by capturing sediment
WHERE APPLICABLE	•	Approximately 2:1 (1V:2H) slopes or flatter.
	•	Low to high velocity reaches.
ADVANTAGES	•	Captures sediment during flood events which helps rebuild the bank.
	•	Produces immediate surface protection against floods.
	•	Establishes dense riparian growth.
CONSTRAINTS	•	Labor intensive.
	•	Gullies may form under mat before brush takes root.
	•	Additional toe protection often necessary.
DESIGN AND CONSTRUCTION GUIDELINES		**Materials**
	•	Approximately 6' long flexible, live brush.
	•	Oak construction stakes (2" x 2"), at least 3' long.
	•	Live Fascine (Practice 502), Riprap (Practice 510), or coconut roll.
	•	Polyethylene net or jute rope.
	•	Sod staples.
	•	Topsoil.

Installation

- Install live fascine, riprap, or coconut fiber log at toe of slope.
- Place live brush on slope with stems tucked under toe protection structure, and stems smooth against the slope.
- Continue placing brush in a shingle pattern up the slope, at least 12" thick.
- Drive stakes perpendicular to the slope in rows, 3' on center, with only a few inches remaining above the brush.
- Place polyethylene net over brush and staple to wood stakes.
- Drive stakes deeper into the bank to tighten the net.
- Cover mattress with 1"-2" of topsoil.
- Broadcast seed a cover crop such as annual and perennial ryegrass.



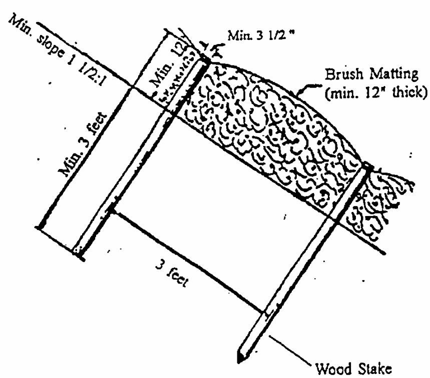


Exhibit 505b: Installation of a brush mattress (Source: DuPage County Streambank Stabilization Program)

Special Considerations

- Brush should contain a diverse assemblage of species recommended in vegetative stabilization technique (Practice 1102), and prepared according to the live stakes method (Practice 501).
- Jute rope may be laced between stakes in a diamond pattern in place of netting; the rope must be stapled to the wood stakes before final driving.
- Make sure there is good branch to soil contact so brush can root along the entire length of the branches.

MAINTENANCE

- Monitor and repair as necessary.
- Beware of gullies forming beneath the mattress before roots become established.

REFERENCES

Related Practices

- Practice 501 Live Stakes.
- Practice 502 Live Fascines.
- Practice 503 Branch Packings.
- Practice 504 Tree Revetments.

Other Sources of Information

- DuPage County Streambank Stabilization Program.
- Watershed Council Shoreline Erosion Guidebook.
- Tennessee Riparian Restoration Handbook.
- Soil Bioengineering Strategies.
- Metropolitan Washington Watershed SourceBook.

PRACTICE 506
VEGETATIVE GEOGRID

DESCRIPTION

- Soil lifts wrapped with natural or synthetic geotextile materials between which are placed layers of live branches.

Exhibit 506a: Vegetative Geogrid (Source: Biotechnical Erosion Control Limited)

PURPOSE

- Rebuilds banks by capturing sediment; reinforces bank.

WHERE APPLICABLE

- Streams with moderate to steep slopes.
- High velocity areas.

ADVANTAGES

- Immediately reinforces bank at a steeper angle.
- Captures sediment and contributes to rebuilding the bank.
- Provides medium for revegetation.

CONSTRAINTS

- Labor intensive.

DESIGN AND CONSTRUCTION GUIDELINES

Materials

- Brush of varying species and lengths (See Practice 501 Live Stakes).
- Suitable soil or soil/gravel fill.
- Vegetative stabilization (See Practice 1102).
- Natural (burlap) or synthetic geotextile fabric.
- 1" x 2" oak stakes, 1' - 2' long.

Installation

- Live cut brush is placed on the ground, perpendicular to the stream.
- Brush is covered with the geotextile.
- Fill material is placed over the geotextile and compacted.

- Geotextile is tightly wrapped around the soil layer and secured with the stakes.
- Live brush is placed between each soil lift.
- Continue the above process until the desired height is achieved. The final level should be finished with branch packings.

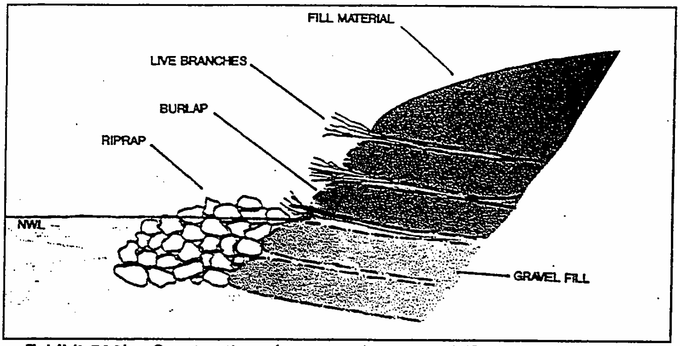


Exhibit 506b: Construction of a vegetative geogrid (Source: CBBEL Files)

Special Considerations

- Gravel fill may be used in the bottom tiers; rock may be placed at the toe of the slope for added protection.

MAINTENANCE

- Monitor and repair as necessary.
- Beware of gullies forming beneath the mattress before roots become established.

REFERENCES

Related Practices

- Practice 502 Live Fascines.
- Practice 507 Live Cribwalls.
- Practice 508 Lunkers.
- Practice 509 A-Jacks.

Other Sources of Information

- DuPage County Stream Stabilization Program.
- Soil Bioengineering Strategies.

PRACTICE 507
LIVE CRIBWALLS

DESCRIPTION	•	A rectangular framework of logs, rock, and woody cuttings used to protect an eroding streambank, especially at outside bends of main channels where strong currents are present, and at locations where an eroding bank may eventually form a split channel.

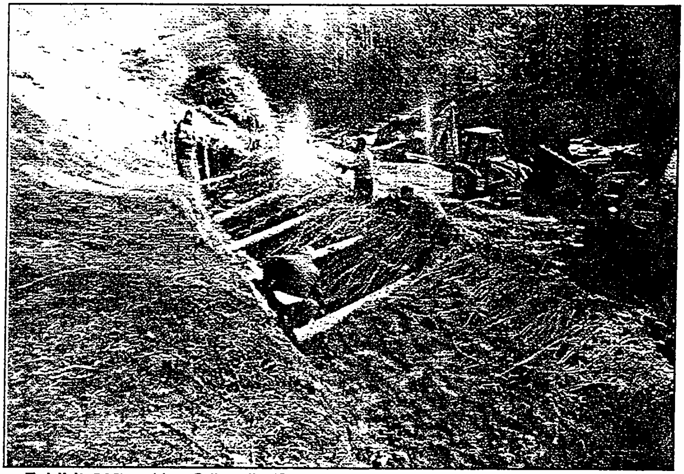


Exhibit 507a: Live Cribwalls (Source: NRCS Engineering Field Handbook)

PURPOSE	•	To protect eroding streambanks.
WHERE APPLICABLE	•	Especially useful at outside bends of main channels with strong currents, and at locations where an eroding bank may eventually form a split channel.
ADVANTAGES	•	Immediate erosion protection.
	•	Permanent and natural appearance.
	•	Improves aquatic and wildlife habitat.
CONSTRAINTS	•	Requires local availability of logs and rocks.
	•	Very labor intensive.
	•	More complex than fascines or branch packings.
	•	May require riprap at end points.
	•	Not applicable where bed is severely eroded as undercutting will occur. Not suitable for rocky terrain or for use in narrow reaches with high banks on both sides.
DESIGN AND CONSTRUCTION GUIDELINES	**Materials**	
	•	Bark free logs at least 6" in diameter.
	•	Plant cuttings (See Practice 501 Live Stakes).
	•	Fill must include granular material to support plant growth.
	•	Timber spikes or rebar.

Installation

- Dig out cribwall base 2 - 3' below existing streambed.
- Place first log parallel to the water's edge, and at bottom of excavated channel.
- Place fiber roll or live fascine at toe of slope.
- Place next layer of logs on top of and perpendicular to first log, approximately 4' apart. Attach logs to each other using spikes or rebar.
- Install Branch Packings (Practice 503) and fill between the logs.
- The top layer should be compacted with fill; the top log should be parallel to the edge of the stream.
- Height of cribbing should be 50-70% of the height of the bank.
- May require riprap at endpoints.
- A double cribwall may be constructed by placing an additional log parallel and adjacent to the bank for each layer.

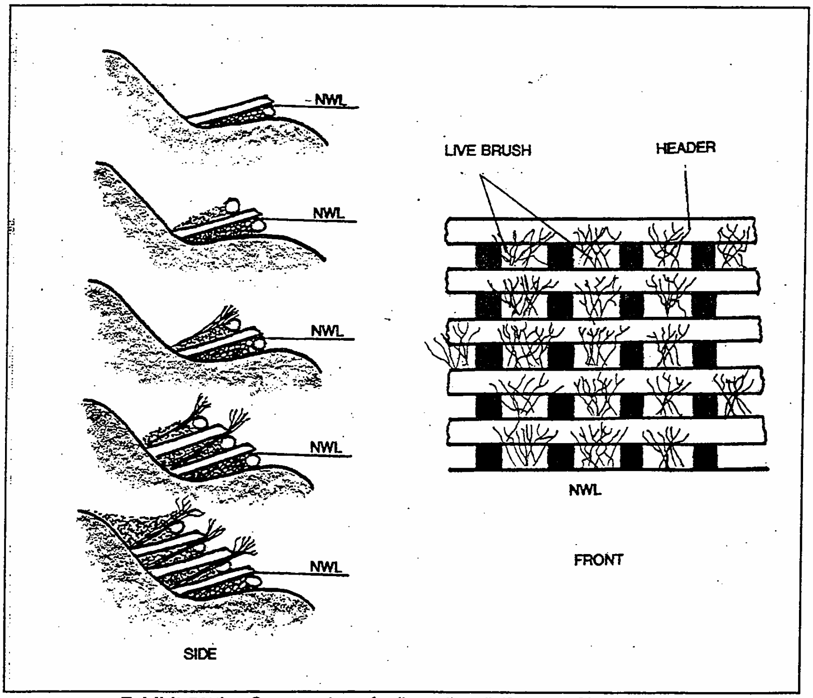


Exhibit 507b: Construction of a live cribwall (Source: CBBEL Files)

Special Considerations

- Live cribwall over 6' tall should not be constructed without the assistance of a knowledgeable professional.

MAINTENANCE	• Low. Monitor and repair as necessary, especially at ends of structure.

REFERENCES

Related Practices

- Practice 502 Live Fascines.
- Practice 508 Lunkers.
- Practice 509 A-Jacks.
- Practice 506 Vegetative Geogrid.
- Practice 510 Stone Riprap.
- Practice 512 Gabion Retaining Wall.

Other Sources of Information

- Pennsylvania Streambank Stabilization Guide.
- Soil Bioengineering Strategies.
- DuPage County Streambank Stabilization Program.
- IWL Streambank Protection Methods.

PRACTICE 508
LUNKERS

DESCRIPTION	•	Oak or plastic (Eco-wood) rectangular boxes built into toe of bank to eliminate scour and provide fish habitat.

Exhibit 508a: Lunkers (Source: CBBEL Files)

PURPOSE	•	Protect toe of bank and provide aquatic habitat.
WHERE APPLICABLE	•	Undercutting at toe of bank.
	•	Approximately 3:1 (1V:3H) slope.
	•	Straight or curved sections.
ADVANTAGES	•	Immediate erosion protection at toe of slope.
	•	Provides habitat.
CONSTRAINTS	•	Labor intensive.
	•	Requires equipment for excavating and backfilling.
DESIGN AND CONSTRUCTION GUIDELINES	**Materials**	
	•	Eco-wood or oak lunker.
	•	5/8" rebar in 5' lengths (9 per lunker)
	•	Geotechnical fabric.
	•	Live Stakes (Practice 501).
	•	Vegetative Stabilization (Practice 1102).

Installation

- Follow procedures for vegetative stabilization.
- Excavate trench in channel at toe of bank so extending end of stringer lies flat across undistributed soil.
- Lay lunkers in trench end to end.
- Drive 9 rebars through each lunker, into streambed.
- Place riprap on top of lunkers, and backfill with excavated material.
- Slope stream bank back at 3:1 (1V:3H) slope and tamp.
- Revegetate disturbed area according to vegetative stabilization method.

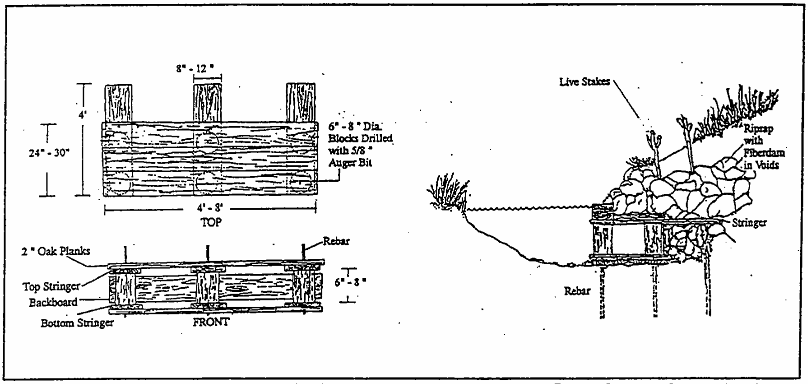


Exhibit 508b: Construction of a lunker structure (Source: DuPage County Streambank Stabilization Program)

Special Considerations

- Only use oak lunkers where baseflow is high enough to completely submerge lunker.

MAINTENANCE

- Low. Monitor and repair as necessary, especially at ends of structure.

REFERENCES

Related Practices

- Practice 501 Live Stakes.
- Practice 502 Live Fascines.
- Practice 503 Branch Packings.
- Practice 506 Vegetative Geogrid.
- Practice 510 Stone Riprap.
- Practice 512 Gabion Retaining Wall.

Other Sources of Information

- DuPage County Streambank Stabilization Program.

PRACTICE 509
A-JACKS

DESCRIPTION

- Concrete, jack-like structures set at toe of bank. Often integrated with live stakes and other vegetative stabilization techniques.

Exhibit 509a: A-Jacks Installation (Source: Illinois State Water Survey Publication)

PURPOSE

- To protect streambanks from the erosive forces of flowing water and to stabilize the soils along the channel bank.

WHERE APPLICABLE

- Along eroded toe.
- Low to high velocity areas.
- Scour holes.

ADVANTAGES

- Protects soil from scour during plant propagation.
- Provides erosion control protection even if vegetation does not become established.
- Immediate erosion protection at toe of slope.
- Improves aquatic and wildlife habitat.

CONSTRAINTS

- Labor intensive.
- Must be used in conjunction with vegetative stabilization.

DESIGN AND CONSTRUCTION GUIDELINES

Materials

- 2' A-Jacks.
- Live Stakes (Practice 501).
- Fiberdam - geotechnical material.
- Vegetative Stabilization (Practice 1102).
- Suitable backfill.

Installation

- Follow preparation procedures for vegetative stabilization.
- Excavate 1' deep trench in channel at toe of bank.
- Lay an interlocking row of A-Jacks in trench.
- Place live stakes according to live stakes method, and fiberdam in voids between A-Jacks.
- Backfill until A-Jacks are completely buried.
- Slope streambank back at 3:1 (1V:3H) slope, if possible, and tamp.
- Revegetate disturbed area according to vegetative stabilization methods.

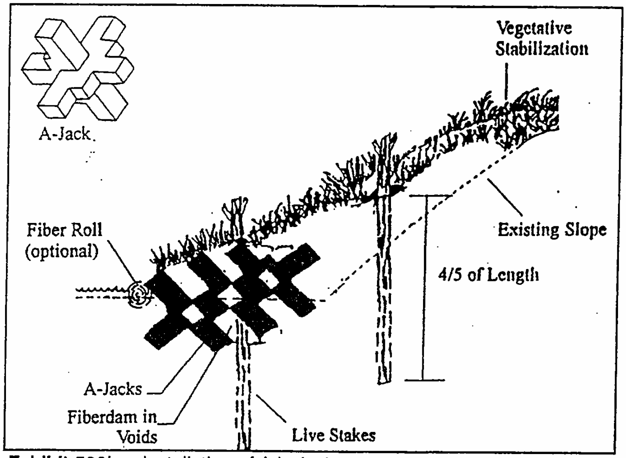


Exhibit 509b: Installation of A-jacks in conjunction with live stakes and vegetative stabilization (Source: DuPage County Streambank Stabilization Program)

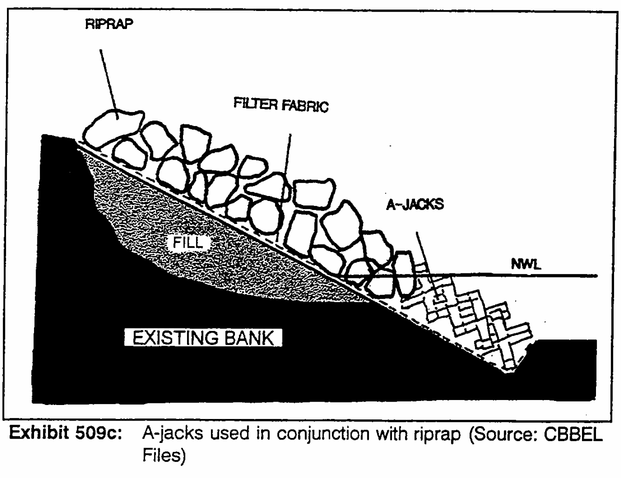


Exhibit 509c: A-jacks used in conjunction with riprap (Source: CBBEL Files)

Special Considerations

- A-Jacks should be stacked above the 5-year high flow elevation and trenched in 2' deep.
- Combine fiber roll with A-Jacks when wave action is evident or immediate natural appearance is desired.
- May be combined with riprap.

REFERENCES

Related Practices

- Practice 501 Live Stakes.
- Practice 502 Live Fascines.
- Practice 503 Branch Packing.
- Practice 506 Vegetative Geogrids.
- Practice 507 Live Cribwalls.
- Practice 508 Lunkers.

Other Sources of Information

- DuPage County Streambank Stabilization Program.
- Illinois State Water Survey Publication.

PRACTICE 510
STONE RIPRAP

DESCRIPTION

- Covering of a portion of a channel bank with a layer of stone that approximates the natural slope of the channel bank. (Note: This practice is also included in the Indiana Erosion Control Handbook.)

Exhibit 510a: Stone Riprap (Source: North Carolina Erosion Control Manual)

PURPOSE	• To protect streambanks from the erosive forces of flowing water.
WHERE APPLICABLE	• On small to medium sized channels and on all character types. • Generally applicable where flow velocities exceed 6 ft/sec or where vegetative streambank protection is inappropriate. • Shaded areas. • Streams where water levels fluctuate. • Actively eroding banks usually along channel curves or wherever it is desirable to reduce the energy of the water.
ADVANTAGES	• Relatively inexpensive, especially compared to other structural methods such as walls. • Flexible and resistant to scour. • Allows for water percolation.
CONSTRAINTS	• Available stone must be able to resist the force of high velocity water flows. • Not recommended on steep slopes or areas where slope cannot be regraded to 2:1 (1V:2H) or flatter. • Hand-placed riprap is labor intensive. • Flooding may wash riprap into stream.

DESIGN AND CONSTRUCTION GUIDELINES

Materials

- Hard, angular and weather-resistant stone having specific gravity of at least 2.5.
- Where available, use local stone. Local stone can often be obtained at lower cost and it also blends better into the existing streambank environment.
- 50% of stone (by weight) must be larger than specified d_{50} and no more than 15% of the pieces (by weight) should be less than 3 inches.
- Geotextile fabric or sand/gravel layer should be used for stabilization under all permanent riprap installations.

Installation

- Remove brush, trees, stumps and other debris.
- Excavate only deep enough for filter and riprap.
- Compact any fill material to density of surrounding natural soil.

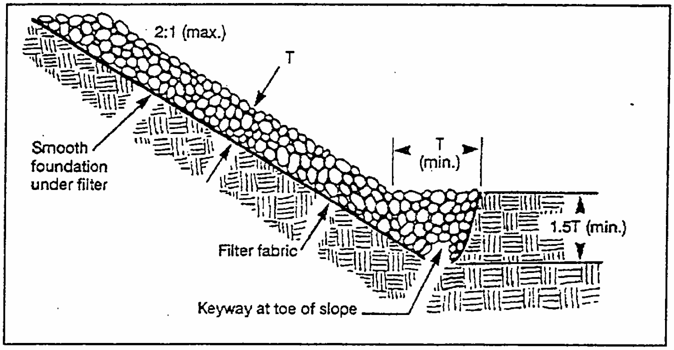


Exhibit 510b: Construction of a riprap bank with toe protection (Source: Indiana Erosion Control Handbook)

- Cut keyway at base of slope to reinforce the toe; keyway depth should be 1½ times the design thickness of the riprap and extend a horizontal distance equal to the design thickness.
- Place geotextile fabric. If using sand/gravel filter, spread the well-graded aggregate in a uniform layer at least 6 inches thick; if 2 or more layers are required, place the layer of smaller gradation first and avoid mixing the layers.
- Add riprap to full thickness in 1 operation.
- Place smaller rock in voids to form a dense, uniform, well-graded mass. Some hand placement of material will most likely be necessary.
- Blend the riprap surface smoothly with the surrounding area to eliminate protrusions or overfalls.
- Riprap may be either hand-placed or dumped.

PRACTICE 511
CONCRETE RETAINING WALL

DESCRIPTION	•	A permanent concrete wall which retains a stream bank.

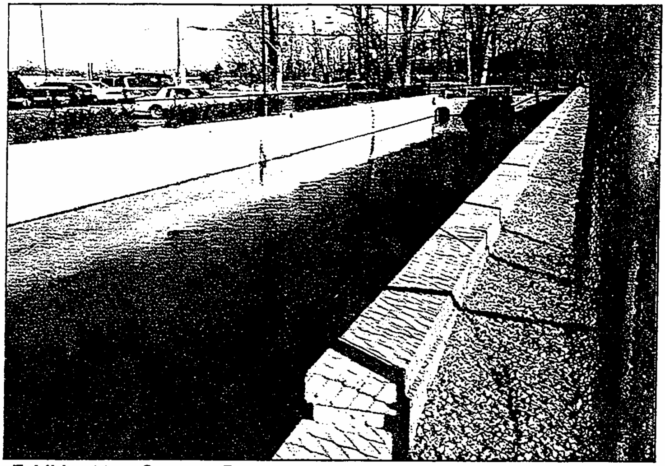


Exhibit 511a: Concrete Retaining Wall (Source: Land and Water Magazine)

PURPOSE	•	Create permanent wall that retains soils, usually along highly eroded and steep to sheer stream channels.
WHERE APPLICABLE	•	Stream channels of all types and sizes.
	•	Stream channels with widely fluctuating water levels, and with high velocities.
ADVANTAGES	•	Low maintenance.
	•	Provides permanent stability.
	•	Prevents erosion and scouring.
CONSTRAINTS	•	Expensive compared to other types of walls.
	•	Requires heavy equipment.
	•	Lacks ecological value.
	•	May exacerbate downstream erosion problems if not installed properly.
	•	Limited to areas with sufficient room for installation.
	•	May be objectionable aesthetically.
	•	Must be designed by an engineer to fit conditions to the site.
DESIGN AND CONSTRUCTION GUIDELINES	**Materials**	
	•	Concrete.
	•	Support structures.
	•	Reinforcing steel (some types).
	•	Forms and formwork.

Installation

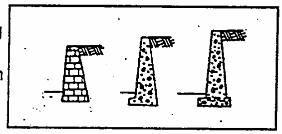
- Assemble general information: topographical and physical surveys, controlling dimensions.
- Analyze subsoil conditions.
- Select type and tentative wall proportions.
- Compute each pressure and surcharge pressure.
- Analyze structural stability.
- Analyze foundation stability.
- Design structural elements.
- Select drainage in backfill.
- Predict settlement and movement of walls.

Special Considerations

- There are five principle types of concrete retaining walls:

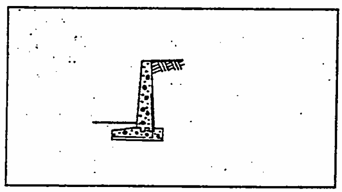
- Gravity Walls: No tensile stress. Heavy construction provides plenty of relative strength, but may not be economical for high walls.

Exhibit 511b: Gravity Retaining Wall (Source: Teng Foundation Design)



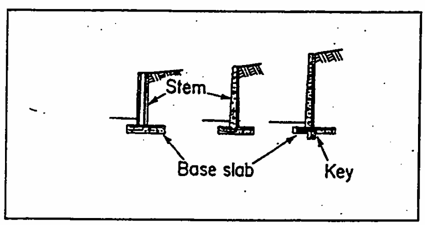
- Semi-Gravity Walls: Some reinforcing steel necessary to reduce the mass of concrete.

Exhibit 511c: Semi-Gravity Retaining Wall (Source: Teng Foundation Design)



- Cantilever Walls: Inverted T forms base and acts as cantilever. Usually made of reinforced concrete, but concrete blocks may be used. Economical for walls $\leq$ 25'.

Exhibit 511d: Cantilever Retaining Wall (Source: Teng Foundation Design)



- Counterfort Walls: Like cantilever walls but with vertical brackets called counterforts on the bank side of the wall.

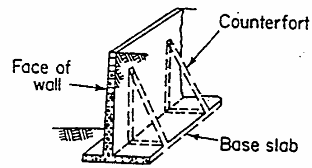


Exhibit 511e: Counterfort Retaining Wall (Source: Teng Foundation Design)

- Butressed Walls: Like counterfort walls but brackets (butresses) are on stream side of wall.

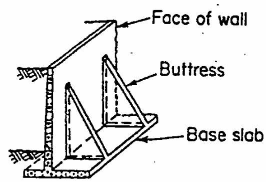


Exhibit 511f: Butressed Retaining Wall (Source: Teng Foundation Design)

MAINTENANCE

- Low.
- Wall settlement can jeopardize the overall integrity of the wall. The potential for settlement can be reduced by overbuilding the wall in excess of the settlement prediction.

REFERENCES

Related Practices

- Practice 507 Live Cribwalls.
- Practice 510 Stone Riprap.
- Practice 511 Concrete Retaining Walls.
- Practice 512 Gabion Retaining Wall.
- Practice 513 Timber Retaining Walls.
- Practice 514 Sheetpile Retaining Walls

Other Sources of Information

- Teng Foundation Design.
- Bulkheads and Seawalls.

PRACTICE 512
GABION RETAINING WALL

DESCRIPTION	•	Rock-filled baskets of wire or plastic. Baskets are wired together to form a wall or mattress for erosion control along a bank or channel.

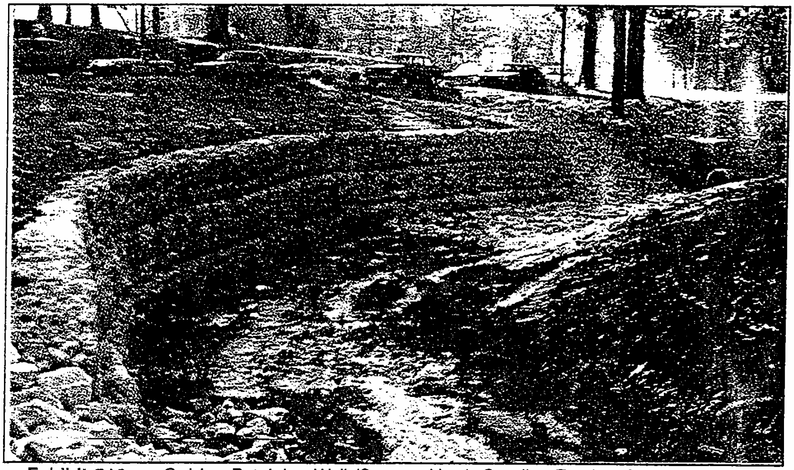


Exhibit 512a: Gabion Retaining Wall (Source: North Carolina Erosion Control Manual)

PURPOSE	•	Protect steep banks where scouring or undercutting are problems.
WHERE APPLICABLE	•	Lining confined channels.
	•	Medium to large size streams and on all character types.
ADVANTAGES	•	Relatively economical when rock fill is available.
	•	Flexible, especially when combined with live plant material.
	•	Very effective in immediately securing unstable streambanks.
CONSTRAINTS	•	Labor intensive.
	•	Skill is required to install correctly.
	•	Expensive to correct if not installed correctly.
	•	Lacks ecological value
	•	May exacerbate downstream erosion problems if not installed properly.
	•	Requires more space than retaining walls.

DESIGN AND CONSTRUCTION GUIDELINES

Materials

- Gabion baskets.
- 4" - 8" rocks for gabions, and 2.5" - 4" for mattresses.
- Filter fabric in highly erodible areas.

Installation

- Gabions and gabion mattresses must be keyed into the streambed to prevent undermining and slumping.

- Empty baskets are wired together and anchored to the streambed.
- Baskets are filled by hand or machine in one foot layers. Two connecting wires are installed with each layer until the gabions are filled.
- Adjoining gabions are wired together by their vertical edges; empty gabions, stacked on filled gabions, are wired to the filled gabions at front and back.
- Baskets are closed and securely laced once filled.
- Gabions may be built as mass gravity structures with wide bases and narrow tops.

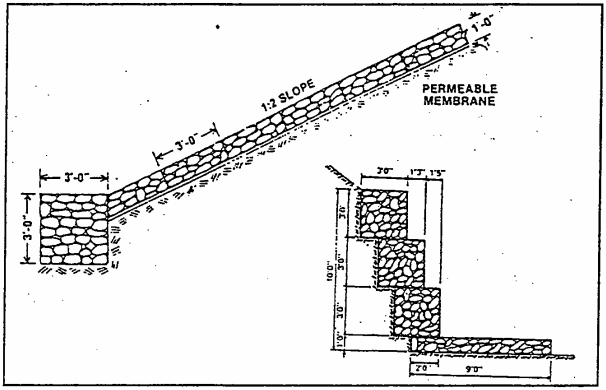


Exhibit 512b: Construction of a gabion retaining wall and mattress (Source: North Carolina Erosion Control Manual)

Special Considerations

- Live Stakes (Practice 501) may be placed between baskets and secured into the soil when used on slopes.

MAINTENANCE

- Low. Monitor and repair as necessary.

REFERENCES

Related Practices

- Practice 501 Live Stakes.
- Practice 511 Concrete Retaining Walls.
- Practice 513 Timber Retaining Walls.
- Practice 514 Sheetpile Retaining Walls.

Other Sources of Information

- Pennsylvania Streambank Stabilization Guide.
- Maccaferri Gabions, Inc. Technical Handbooks.

PRACTICE 513
TIMBER RETAINING WALL

DESCRIPTION
- A permanent timber wall which retains a streambank.

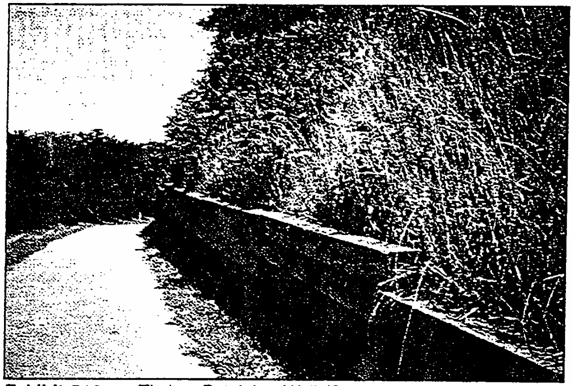


Exhibit 513a: Timber Retaining Wall (Source: NRCS Engineering Field Handbook)

PURPOSE
- Create permanent wall that retains soils, usually along highly eroded and steep to sheer stream channels.

WHERE APPLICABLE
- Stream channels of all types and sizes.
- Stream channels with widely fluctuating water levels, and with high velocities.
- Wall heights up to 4' differential.

ADVANTAGES
- May use less skilled labor and lighter material than other walls.
- Can be adapted to a range of stream bank configurations.
- Low maintenance.
- Prevents erosion and scouring.

CONSTRAINTS
- Expensive.
- Limited to areas with sufficient room for installation.
- May be objectionable aesthetically.
- Lacks ecological value and may be discouraged by agencies due to concerns about potential negative impacts of treated lumber or plastic especially where constant or considerable contact exists with water.
- May exacerbate downstream erosion problems if not installed properly.
- Must be tied back at heights above 3' which may require excavation.
- Less permanent than stone or concrete walls.

DESIGN AND CONSTRUCTION GUIDELINES

Materials
- Wood timbers treated with a preservative.
- Steel bins.
- Open graded granular backfill.

Design

- Assemble general information: topographical and physical surveys, controlling dimensions.
- Analyze subsoil conditions (visual; requires geotechnical report if over 3' high).
- Select type and tentative wall proportions.
- Compute earth pressure and surcharge pressure (over 3' high).
- Analyze structural stability (over 3' high).
- Analyze foundation stability (over 3' high).
- Design structural elements (over 3' high).
- Select drainage in backfill.

Installation

- Establish firm foundation soil. Put in at least 6". Open graded gravel as bedding.
- Lay successive courses of timbers with offset joints.
- Every fourth course, turn a timber at least as long as the height of the wall perpendicular and embedded in the soil behind the wall with a steel pin.
- Backfill with open graded aggregate and compact with each horizontal course.

Special Considerations

- The space behind the wall must be free draining so that the water pressure differentials caused by stream fluctuations are minimized.
- Wall heights over 3' should be reviewed by a structural engineer prior to installation.

MAINTENANCE

- Check for rotting timbers and replace as necessary.
- Wall settlement can jeopardize the overall integrity of the wall. The potential for settlement can be reduced by overbuilding the wall in excess of the settlement prediction.
- Watch for erosion at the wall base as undermining is often the cause of wall failure.

REFERENCES

Related Practices

- Practice 507 Live Cribwalls.
- Practice 510 Stone Riprap.
- Practice 511 Concrete retaining Walls.
- Practice 512 Gabion Retaining Wall.
- Practice 513 Timber Retaining Walls.
- Practice 514 Sheetpile Retaining Walls.

Other Sources of Information

- Teng Foundation Design.
- Bulkheads and Seawalls.

PRACTICE 514
SHEETPILE RETAINING WALL

DESCRIPTION
- Steel, concrete, wood, or plastic sheet piles that interlock to form a continuous wall along a stream channel. The wall may be partially supported by anchors imbedded in the soil behind the wall, called tie-backs.

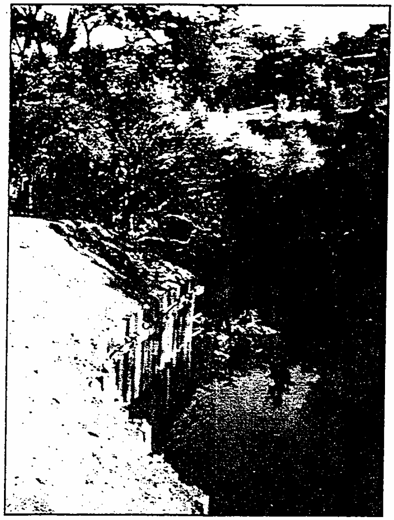


Exhibit 514a: Sheetpile Retaining Wall
(Source: NRCS Files)

PURPOSE
- Create a temporary or permanent wall that retains soils, usually along highly eroded and steep to sheer stream channels.
- Where land ownership or rights prohibit flattening a slope or other types of armor.

WHERE APPLICABLE
- Stream channels of all types and sizes.
- Stream channels with widely fluctuating water levels, and with high velocities.
- Where permanent channel obstructions such as bridge abutments cause significant erosion.

ADVANTAGES
- Low maintenance.
- Provide permanent stability if necessary.
- Prevents erosion and scouring in immediate area of sheet piling.
- May be used along channels where space prohibits the construction of other structures that require more space to work.

CONSTRAINTS
- Expensive.
- Requires heavy equipment.
- Should not be used in areas where boulders or bedrock would

prevent driving piles to the appropriate depth.

- Should not be used to create very high walls in which the flexural strength of the wall might be compromised.
- May be objectionable aesthetically.
- Lacks ecological value and may be discouraged by agencies due to concerns about potential negative impacts of treated lumber or plastic especially where constant or considerable contact exists with water.
- May exacerbate downstream erosion problems if not installed properly.
- Must be reviewed by a structural engineer for stability.
- May transfer erosion downstream from sheeting if not properly transitioned.

DESIGN AND CONSTRUCTION GUIDELINES

Materials

- Rolled steel, precast concrete, wood or plastic piles.
- May require anchoring structures such as cantilevers or tie rods.

- Steel: Interlocking, rolled steel sheet piles of varying weights driven into the ground. Steel is the most widely used pile material.

- Wood: Independent or tongue-and-groove interlocking planks driven edge to edge into the ground. May be permanent if permanently inundated, though generally used as a temporary structure for short to moderately high walls.

- Concrete: Precast, concrete piles driven side by side into the ground. Long service life but high initial costs. Concrete piles are more difficult to handle and drive than steel piles. May be useful in streams with high abrasion, and where the wall must support an axial load. Can induce settlement in soft foundations.

- Plastic: High density, interlocking plastic sheets. Usually vibrated into the ground. Plastic has lower structural capacities than other materials and is generally used in tie-back situations.

Installation

- The most common methods for installing sheetpiling include driving, jetting and trenching. The type of sheetpiling used usually governs the method of installation.
- Driving: Sheetpiling is typically driven with traditional pile driving equipment.
- Jetting: Water jets are sometimes necessary when driving piles into dense, cohesionless soils. Jetting should be performed on both sides of piling simultaneously but must be discontinued during the last 5'-10' of penetration.
- Trenching: Usually necessary when pile penetration is shallow and driving is impossible.
- Sheetpile retaining walls should be designed by a qualified engineer and installed in accordance with the manufacturer's specifications.

Special Considerations

- Anchored walls are required when the height of the wall exceeds heights recommended for cantilever walls, or when lateral deflections are a consideration. Proximity of an anchored wall to an existing structure is governed by the horizontal distance required for the installation of an anchor.

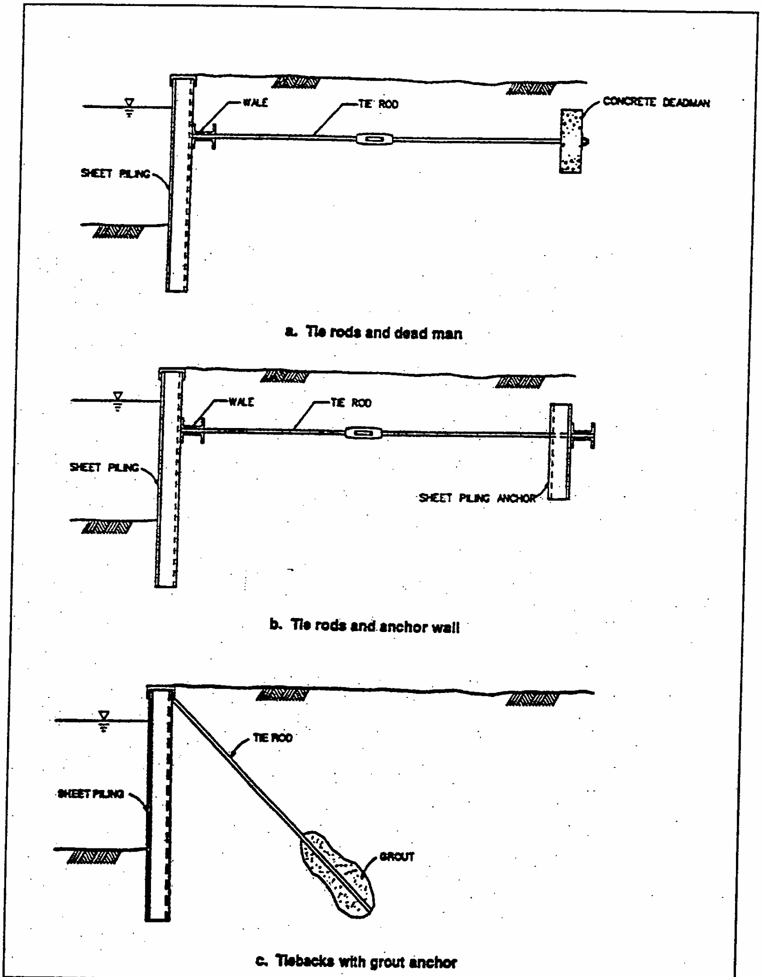


Exhibit 514b: Anchored walls (Source: COE Engineering Manual)

- Cantilever walls are usually used as floodwalls or earth retaining walls < 10' - 15' high. Cantilever walls derive their support solely from foundation soils so they may be installed relatively close ($\geq$ 1.5 times the length of the piling) to an existing structure.

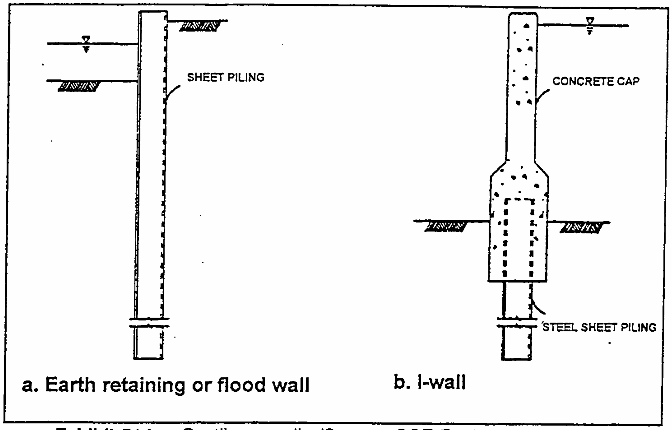


Exhibit 514c: Cantilever walls (Source: COE Engineering Manual)

- A geotechnical investigation should be conducted to identify foundation conditions, and to assist in the choice of pile material and design.
- An evaluation of system loads applied to the piling should be conducted prior to designing a wall. Loads governing the design arise primarily from the soil and water surrounding the wall, and other influences such as surface surcharges, and external loads applied directly to the piling.

MAINTENANCE

- Low.
- Uncapped, exposed sheet piling corrodes at varying rates averaging 2 - 10 mils per year, depending on surrounding atmospheric conditions. Sheetpiling driven into natural, undisturbed soils has a negligible corrosion rate. Increased erosion occurs with piles installed in organic or fresh fills.
- Wall settlement can jeopardize the overall integrity of the wall. The potential for settlement can be reduced by overbuilding the wall in excess of the settlement prediction.

REFERENCES

Related Practices

- Practice 507 Live Cribwalls.
- Practice 508 Stone Riprap.
- Practice 511 Concrete Retaining Walls.
- Practice 512 Gabion Retaining Walls.
- Practice 513 Timber Retaining Walls.
- Practice 515 Composite Retaining Walls.

Other Sources of Information

- COE Engineering Manual.

PRACTICE 515
COMPOSITE RETAINING WALL (Soldier Pile with Sheeting)

DESCRIPTION

- A permanent retaining wall in which timber or pre-cast concrete are installed horizontally between steel I-beam piles.

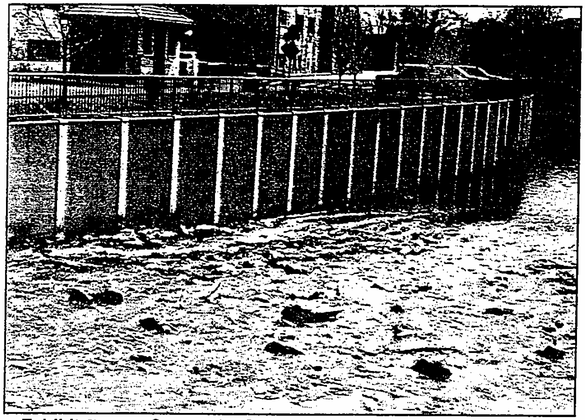


Exhibit 515a: Composite Retaining Wall (Source: CBBEL Files)

PURPOSE

- Create a temporary or permanent wall that retains soils, usually along highly eroded and steep to sheer stream channels.

WHERE APPLICABLE

- Stream channels of all types and sizes.
- Stream channels with widely fluctuating water levels, and with high velocities.

ADVANTAGES

- Low maintenance.
- Provide permanent stability if necessary.
- Prevents erosion and scouring.
- May be used along channels where space prohibits the construction of other structures that require more space to work.
- May be more aesthetically acceptable than sheetpiling.

DISADVANTAGES

- Expensive.
- Requires heavy equipment.
- Should not be used in areas where boulders or bedrock would prevent driving piles to the appropriate depth.
- Should not be used to create very high walls in which the flexural strength of the wall might be compromised.
- Lacks ecological value and may be discouraged by agencies due to concerns about potential negative impacts of treated lumber or plastic especially where constant or considerable contact exists with water.
- May exacerbate downstream erosion problems if not installed properly.

- Requires professional design and geotechnical review.

DESIGN AND CONSTRUCTION GUIDELINES

Materials

- Steel I-beam piles.
- Pre-cast concrete sheets, tongue and groove wood planks, or railroad ties.

Installation

- Assemble general information: topographical and physical surveys, controlling dimensions.
- Analyze subsoil conditions.
- Analyze structural stability.
- Analyze foundation stability.
- Design structural elements.
- Predict settlement and movement of walls.

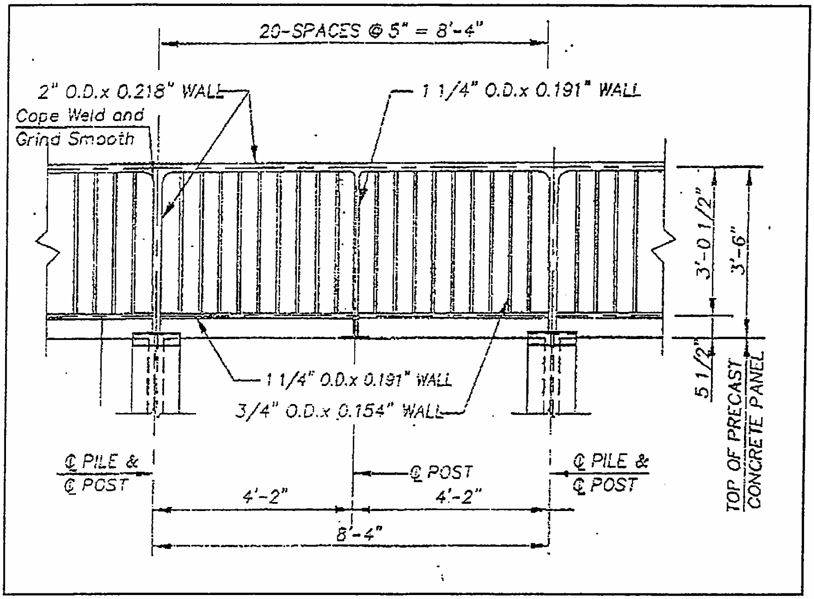


Exhibit 515b: Typical Example of a Composite Wall Design (Source: CBBEL Files)

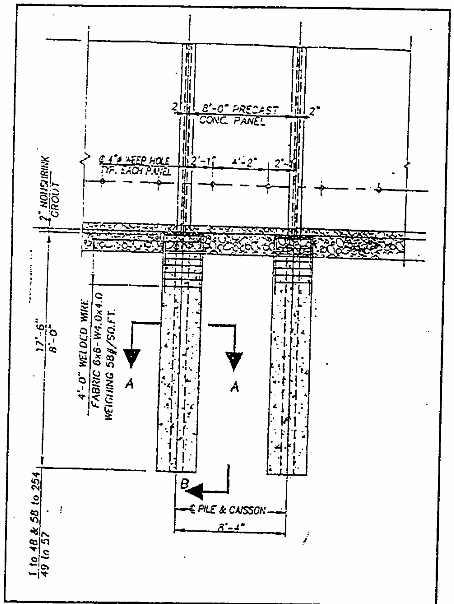


Exhibit 515c: Typical Example of a Composite Wall's Pile and Post Design Details (Source: CBBEL Files)

Special Considerations

- A geotechnical investigation should be conducted to identify foundation conditions, and to assist in the choice of pile material and design.
- An evaluation of system loads applied to the piling should be conducted prior to designing a wall. Loads governing the design arise primarily from the soil and water surround the wall, and other influences such as surface surcharges, and external loads applied directly to the piling.

MAINTENANCE

- Low.
- Wall settlement can jeopardize the overall integrity of the wall. The potential for settlement can be reduced by overbuilding the wall in excess of the settlement prediction.

REFERENCES

Related Practices

- Practice 510 Stone Riprap.
- Practice 511 Concrete Retaining Walls.
- Practice 512 Gabion Retaining Walls.
- Practice 513 Timber Retaining Walls.

Other Sources of Information

- COE Engineering Manual.

APPENDIX H

Public Information Handout

To be provided.

WHAT CAN WE DO? ...IN THE WATERSHED

HOMEOWNERS

* Never dump anything into a sinkhole
* Check and maintain your septic system regularly
* Always read and follow label directions when using household, lawn, or farm chemicals.

FARMERS

* Use fencing to exclude/limit livestock access to sensitive areas
* Use filter strips to remove sediment and nutrients from runoff.
* Provide watering troughs/tanks for livestock on pasture.
* Use BMPs for grazing.

CONTRACTORS

* Install & maintain erosion control measures.
* Seed disturbed areas promptly

...IN THE STREAM

* Exclude livestock
* Maintain/repair streambanks

For additional information on how to enhance the water quality of Indian Creek

&

to learn more about Best Management Practices for the watershed,

Contact:

Greene County SWCD
30 W. Indiana Ave.
Bloomfield, IN 47424
(812) 384-4634

Lawrence County SWCD
1919 Stevens Ave.
Bedford, IN 47421
(812) 275-4365

Martin County SWCD
P.O. Box 34
Shoals, IN 47581
(812) 247-2423

Monroe County SWCD
1931 Liberty Drive
Bloomington, IN 47403
(812) 334-4325

Brochure and Diagnostic Study by:

Donan Engineering Co., Inc.
4342 N. Hwy. 231
Jasper, IN 47546
Ph. (812) 482-5611

INDIAN CREEK DIAGNOSTIC STUDY

Sponsored By the Soil & Water Conservation Districts of Greene, Lawrence, Martin, & Monroe Counties

Indian Creek Watershed is approximately 110,000 acres in size and the 43 miles of main channel is a tributary of the East Fork of the White River. The headwaters are found near Stanford in Monroe County and the sinuous stream meanders through Greene and Lawrence Counties until the confluence is reached near Shoals in Martin County.

A Watershed Diagnostic Study was performed to :

* Describe Existing Conditions
* Identify Potential Non-point Source Pollution Problems
* Propose Recommendations

The Indian Creek Watershed has five main sub-watersheds including:

* Opossum Creek
* Sulphur Creek
* Spring Creek
* Popcorn Creek &
* Little Indian Creek

Nearly 15,000 acres of the Indian Creek Watershed are controlled government lands at the Crane Navy Base. The watershed has interesting geologic features including karst topography in the headwaters area and springs near the mouth of the stream.

Findings. At least 80 % of the soil in the watershed is Highly Erodible Land or potentially highly erodible. As a result, much of the open land is used for pasture/hay instead of row crops. Cow-calf operations are a significant enterprise in the watershed.

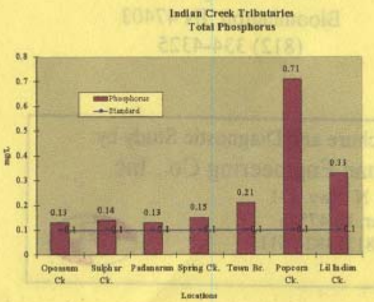
Livestock grazing on pasture can contribute to nonpoint source pollution to streams.

Overgrazing:

* Exposes soils
* Increases erosion
* Encourages invasion by weeds
* Reduces filtration of sediment

Cattle, if allowed, will spend excess time near the stream corridor as compared to drier upland areas where the forage is less palatable. Manure loading into Indian Creek from "Direct Deposits" adds Nitrogen, Phosphorus, and Potassium in addition to sediments. It is estimated that a 1,000 lb. beef cow produces 60 lb. of manure per day and, during the summer, 2 lb. per cow per day will be directly deposited if she has access to the stream.

Phosphorus is the most important factor in the cultural eutrophication of streams and since phosphorus is the nutrient in shortest supply, even a modest increase in phosphorus can set off a whole chain of undesirable events including accelerated plant growth, algae blooms, low dissolved oxygen, and the death of certain fish, invertebrates, and other aquatic animals.



Sampling indicated that Phosphorus levels in the main tributaries of Indian Creek– especially Popcorn Creek- exceeded State standards.

It has been reported that 9% of the water quality problems in our streams are related to forestry activities.

Sources of nonpoint source pollution caused by forestry activities include:

* Removal of streamside vegetation
* Logging road construction & use
* Timber harvesting, &
* Mechanical preparation of tree planting areas

There are no sanitary sewer services in the Indian Creek Watershed, therefore all residents rely on on-site disposal systems– septic tanks. Soils found in the watershed generally are, at best, marginally suited for septic system absorption fields.

Septic systems have been identified as sources of groundwater pollution and nonpoint source pollution to surface waters. The major pollutants associated with septic systems are nitrates and bacteria. Some potential inorganic contaminants from septic systems include chlorides, phosphorous, and metals. Phosphorus is not really harmful to humans however it is a major contributor to eutrophication in surface waters. Metals in the effluents from septic tank systems may be responsible for the contamination of shallow water supply sources, such as where there is a high groundwater table.